THE AETIOLOGY AND MODIFICATION OF FOOD PREFERENCES IN EARLY CHILDHOOD

Alison Fildes

A thesis submitted for the degree of Doctor of Philosophy

UCL

DECLARATION

I, Alison Fildes, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ACKNOWLEDGEMENTS

I would like to express my thanks to Professor Jane Wardle, for providing me with the unique opportunity to work on the Gemini study, for her unwavering encouragement when I first considered pursuing a PhD and her continued guidance and inspiration. I am also forever indebted to Dr Lucy Cooke and Dr Ellen van Jaarsveld whose combined knowledge and support have been invaluable over the past three years. Without your shared insight, enthusiasm and most of all patience this thesis would not have been written.

A special thanks to Clare Llewellyn, a fantastic teacher and friend, whose expertise on twins and quantitative genetic modelling (among many other topics) proved invaluable. I am also grateful to Marion Hetherington for her thoughtful and constructive input during my upgrade from MPhil.

Many thanks to my friends and colleagues at the HBRC who have provided endless practical, intellectual and emotional support. In particular I would like to thank my fellow PhD students, and the members of the Gemini team past and present, including Abi, Laura J, Steph and Susie, to name but a few, who have made me think and laugh in equal measure.

I am grateful to the many Gemini families who completed lengthy questionnaires and intervention procedures which made this research possible. I would also like to acknowledge CRUK, and UCL for their financial and administrative support.

Finally, thank you to my friends and family; particularly my parents who have always been my greatest supporters, my sisters Jenny and Laura for their humour, perspective and Laura's baked goods, and to Sam for enduring this alongside me, and for providing constant encouragement, advice and references.

ABSTRACT

Poor diet contributes to the global burden of disease and food preferences play an important role, especially for children. Children generally like sweet, energy-dense foods and often dislike vegetables. However, there are considerable individual differences in liking and explanations for this variation remain elusive. This thesis uses data from a UK cohort of twins to examine the aetiology and development of children's food preferences with the aim of informing effective dietary interventions. Study 1 explored the underlying structure of children's preferences and found that empirically-derived food groups reflected traditional food categories. In infancy and childhood, liking for foods in the energy-dense snack food group were high and liking for vegetables was low. Study 2 investigated family and child characteristics associated with children's food preferences and showed that maternal diet and children's appetitive traits, particularly food fussiness, were strongly related to preferences. Study 3 used a twin design to investigate genetic and environmental influences on food preferences. Genetic effects on liking were strongest for vegetables, fruit and protein, while shared environmental effects were more important in liking for dairy and snack foods. Study 4 revealed common genetic influences behind vegetable liking and food fussiness, which explained the majority of the covariation between them. Study 5 was an RCT of parent-delivered taste exposure to modify children's vegetable acceptance. Intake and liking of a vegetable increased significantly more in intervention participants than controls, although individual variation in intervention response remained. Finally, Study 6 investigated whether variation in intervention response was genetically determined, but found that individual differences were primarily environmentally determined. This thesis provides evidence that genetically-determined food preferences are present in early life, particularly for nutritious foods like fruits and vegetables. In addition, Study 5 suggests that these inherited patterns of preference may be effectively modified using targeted interventions in childhood.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 4

Chapter 5

Chapter 6

Chapter 7

LIST OF FIGURES

Chapter 8

Chapter 9

CHAPTER 1 . THE DEVELOPMENT OF FOOD PREFERENCES IN EARLY LIFE

1.1. The implications of food preferences for diet and health

A varied diet is fundamental to good health, and the modern food environment offers easy access to a diverse range of foods. In such circumstances where food availability and variety are high, people tend to select the foods they find most palatable. Human beings are predisposed to prefer foods that are high in energy (Steiner, 1979; Tiger, 1992) rather than those that are most nutritious. The combination of the modern food environment and people's innate preference patterns is contributing to a global 'nutrition transition' whereby traditional, plant-based diets rich in fruits and vegetables are being replaced with energy-dense diets, high in fats and sugars (Popkin, 2001).

Poor dietary quality has implications for many chronic non-communicable diseases, such as coronary heart disease, diabetes and some cancers, which are the current leading cause of mortality and morbidity worldwide (World Health Organization, 2002). The economic costs of poor nutrition are also extensive and in the UK alone, treatment of disease and ill health resulting from poor diets is estimated to be costing the National Health Service £5.8 billion annually (Scarborough et al., 2011).

Children's food preferences in particular, do not align with dietary recommendations (Russell & Worsley, 2007) and when listing their favourite foods children typically rate fatty and sugary foods the highest and vegetables the lowest (Cooke & Wardle, 2005). Preferences for energy-dense foods are reflected in children's intake of fat and sugar with increasingly younger children consuming energy-dense foods regularly. An American survey of nine to twelve month old infants found 43% were consuming a sweet snack food (excluding fruit desserts) such as cookies, cakes, sweets or sweetened beverages every day and this increased to 80% among 21 to 24 month olds (Siega-Riz et al., 2010). These unhealthy dietary patterns are associated with multiple negative health outcomes, including childhood obesity (Epstein et al., 2001; Ness et al., 2005). There is a global epidemic of overweight and obesity and the condition is developing progressively earlier in childhood. UK national statistics (Health Survey for England, 2008) indicate that in 2004, 14% of two to ten year olds were obese; almost three times the number in 1990. The consequences of childhood obesity for paediatric health include among others; adverse psychosocial effects (Puhl & Brownell, 2001), raised risks of asthma (Chinn, 2006) and type II diabetes (Haines, Wan, Lynn, Barrett, & Shield, 2007). The negative health consequences are seen in both the short and longer-term as children tend to maintain their relative BMI position into adulthood (Baird et al., 2005; Parsons, Power, Logan, & Summerbell, 1999).

Unhealthy diets are characterised by an overconsumption of energy-dense foods, and inadequate intake of nutrient-rich foods such as fruits and vegetables. Fruits and vegetables[1] have long been known to play a key role in dietary health and sufficient intake of these provides children with essential nutrients for healthy growth and development (World Health Organization, 2003). More recently, extensive research has linked inadequate fruit and vegetable consumption with a range of negative health outcomes in adulthood including cardiovascular disease (Hu & Willett, 2002; Joshipura et al., 2001; Liu et al., 2000; Ness et al., 2005; Rimm et al., 1996), stroke (He, Nowson, & MacGregor, 2006; Joshipura et al., 1999), type II diabetes (Carter, Gray, Troughton, Khunti, & Davies, 2010) , and some cancers (Steinmetz & Potter, 1996; World Health Organization, 2003, 2011). There is also evidence that higher fruit and vegetable consumption in childhood is associated with immediate beneficial impacts, including a reduction in the risk of micro-nutrient deficiencies and a number of respiratory illnesses (Antova et al., 2003; Forastiere et al., 2005; World Health Organization, 2003), reduced blood pressure throughout childhood and later in life (Moore et al., 2005) and bone density in adolescence (Tylavsky et al., 2004)

The World Health Organisation (WHO) has estimated that 2.9% of all deaths globally and 1.1% of all disability-adjusted life years (DALYs) annually are a consequence of inadequate fruit and vegetable consumption (World Health Organization, 2009). Within Europe, it has been estimated that 4.4% of the overall burden of disease is attributable to inadequate intake of fruits and vegetables (World Health Organization, 2002). It has also been suggested that increased intake of fruits and vegetables might help to displace energy-dense, nutrient-poor foods associated with childhood overweight and obesity (Epstein et al., 2001; Tohill, 2005; Wosje et al., 2010).

The minimum recommended daily intake of fruits and vegetables needed to reduce chronic disease risk is 400 grams for adults (World Health Organization, 1997), but throughout the world nationally representative surveys suggest daily consumption of fruits and vegetables falls well below recommendations (Lock, Pomerleau, Causer,

[1] The definition of fruits and vegetables is not always clear and can vary between countries. In North America potatoes (often including French fries) are categorised as vegetables but in Europe they are typically excluded as they lack the vitamins (with the exception of vitamin C) and minerals contained in other vegetables and are therefore grouped with carbohydrates.

Altmann, & McKee, 2005). For children, guidelines for intake are less clear and adequate quantities are likely to vary according to age and development. Nonetheless, population surveys consistently highlight the global need to increase children's intakes of fruits and vegetables (Currie et al., 2004; Lock et al., 2005; Yngve et al., 2005). In Europe, while intake levels vary between countries, less than a third of school-aged children report eating vegetables on a daily basis (Currie et al., 2004). The 2002 Health Survey for England (Sproston & Primatesta, 2003) reported that English children aged between five and fifteen years old consumed only 2.5 portions of fruits and vegetables per day on average. Data relating to preschool children's fruit and vegetable consumption is limited, but there are findings suggesting intake is also inadequate in this age group. A study of American children found that toddlers consumed relatively few vegetables, and of the top 5 vegetables eaten none were dark green vegetables (Fox, Pac, Devaney, & Jankowski, 2004; Mennella, Ziegler, Briefel, & Novak, 2006). More recently, the 2008 US Infants and Toddlers Survey found almost 30% of children aged six months to two years were consuming less than one vegetable per day (Siega-Riz et al., 2010). The ALSPAC study in the UK investigated three year old children's average daily consumption of fruit and vegetables and reported intakes of only 69g for fruit and 40g for vegetables (Emmett, Rogers, & Symes, 2002).

Given that longitudinal studies suggest that eating behaviours and food preferences established in infancy and early childhood are likely to persist into adulthood (Bjelland et al., 2013; Lien, Lytle, & Klepp, 2001; Northstone & Emmett, 2008) interventions targeting young children's dietary patterns may be particularly effective in improving lifelong health and reducing chronic disease risk. However, in order to modify children's eating behaviours we must first understand the aetiology of these traits. Children's food intake is mediated by a number of factors including, but not limited to; availability, parental control, social environment, appetite, eating behaviours and preferences. Research has repeatedly shown food preferences to be key predictor of children's dietary intake (Baxter & Thompson, 2002; Bere & Klepp, 2004; Cullen et al., 2003; Gallaway, Jago, Baranowski, Baranowski, & Diamond, 2007; Gibson, Wardle, & Watts, 1998; McClain, Chappuis, Nguyen-Rodriguez, Yaroch, & Spruijt-Metz, 2009; Resnicow et al., 1997) and therefore, the current review will focus primarily on the development of food preferences in early childhood.

1.2. Background and definition of food preferences[2]

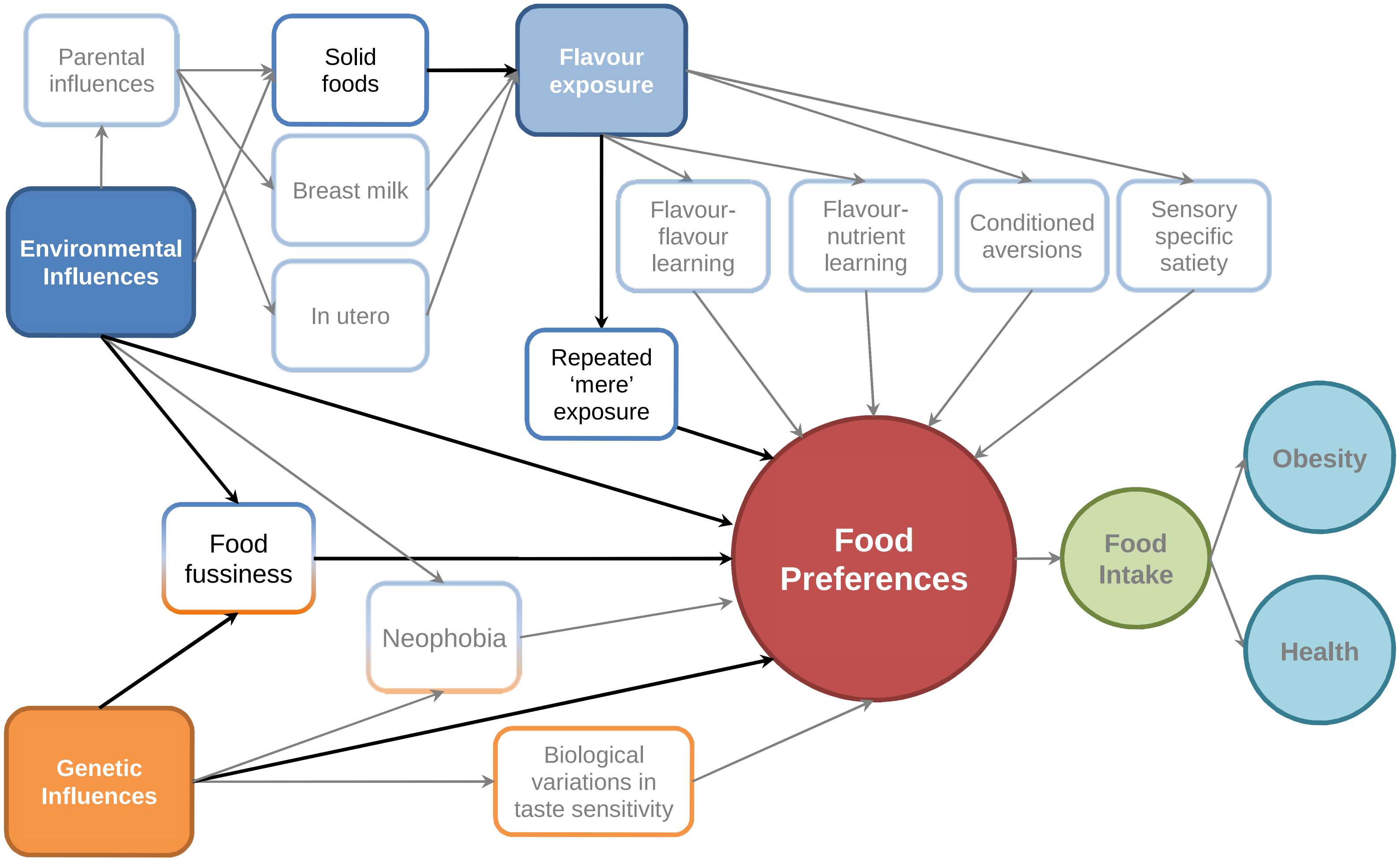
Flavour is experienced via a combination of three chemical senses; taste, smell and chemosensory irritation (Beauchamp & Mennella, 2009). Taste is detected by receptor cells in the tongue and palate and is generally classified into five variants; sweet, salty, bitter, sour and umami (savoury). Smell is the perception of odours (volatile compounds) via stimulation of the receptors in the top part of the nasal cavity. The third component of flavour, chemosensory irritation refers to stimulation of receptors and nerve endings in the brain that lead to the perception of heat, coolness, pain etc.; it is this sense that detects the ‘heat’ of hot chili peppers (Beauchamp & Mennella, 2009; Cooke & Fildes, 2011).

There are universal human predispositions to learn to prefer certain characteristics of food that seem to transcend cultural variation. Energy-dense foods that are high in fat such as chips and pizza, and sugary or sweet foods such as ice cream or chocolate are consistently among children’s most liked foods throughout Europe (Bellisle, Rolland-Cachera, & Nu, 2000; Cooke & Wardle, 2005; Diehl, 1999; Skinner, Carruth, Wendy, & Ziegler, 2002), the United States (Skinner, Carruth, Wendy, et al., 2002) and Australia (Russell & Worsley, 2007). An innate preference for sweet and dislike of bitter tastes has also been repeatedly demonstrated in newborn infants (Beauchamp & Moran, 1982; Desor, Maller, & Turner, 1973), and continues to be strong in early childhood, although this preference for sweet tastes is less pronounced in adults (Vazquez, Pearson, & Beauchamp, 1982).

Multiple genetic and environmental factors combine to shape an individual’s unique pattern of food preferences. Figure 1.1 attempts to graphically describe the multiple factors contributing to food preferences that will be addressed in the current literature review. The concepts of particular relevance to the current thesis are emphasised in colour within the diagram.

[2] The definition of preference is ‘a greater liking for one alternative over another or others’. However in dietary literature the term ‘preference’ has often been used interchangeably with ‘liking’ to describe an individual’s propensity to enjoy one particular food type or food group, without necessarily drawing comparisons. I will similarly be using the term ‘preference’ synonymously with ‘liking’ throughout this thesis.

Figure 1.1: The development of food preferences; important influences



1.3. Environmental influences on the development of food preferences[3]

Humans are born with some genetically determined predispositions, such as a liking for sweet tastes and a dislike for bitter and sour tastes. Around the second year of life a tendency to avoid novel foods (neophobia) often emerges which may result in a reduced variety of foods liked. Individual variations in such predispositions, and in food preferences generally, appear be to some extent genetically determined and heritable (Breen, Plomin, & Wardle, 2006; Cooke, Haworth, & Wardle, 2007; Scaglioni, Arrizza, Vecchi, & Tedeschi, 2011). Nevertheless, from birth, and perhaps even before, genetic predispositions are susceptible to modification through experience. Food aversions can be acquired after only one incident of digestive disturbance, and liking for foods can be enhanced through familiarity. In this context, the flavour environment in utero, and parental feeding practices and the home food environment in infancy and early childhood play a vital role in the development of food preferences.

1.3.1. Exposure

Food preferences are developed through exposure to specific flavours; people become more familiar with foods the more they experience and taste them, which in turn results in greater preference for these foods over time. In essence, children like the foods they know and eat the foods that they like (Wardle & Cooke, 2008). This observation underpins a considerable body of research into the impact of taste exposure on children's food preferences which has almost unanimously concluded that regular and repeated exposure to a particular food is extremely effective in increasing liking and consumption of that food from infancy to school-age and beyond (Cooke, 2007; Wardle, Cooke, et al., 2003). Even substances considered to be innately unpalatable, such as chili pepper, are commonly accepted and liked by children growing up in cultures where they are widely used and routinely offered to children from an early age (Ludy & Mattes, 2012; Rozin, Gruss, & Berk, 1979). It is clearly a positive adaptive strategy for children to develop preferences for the foods that are locally available to them.

---

[3] Some of the information provided in this section has been published in the following paper: Cooke L. and Fildes A. (2011). The impact of flavour exposure in utero and during milk feeding on food acceptance at weaning and beyond. *Appetite, 57,* 808-811.

Learned preferences extend beyond acceptance of individual foods and dishes to include the time and context in which specific foods are considered palatable. In many Asian countries, rice and noodle dishes or soups, often with meat and vegetables, are common breakfast foodstuffs. Contrastingly, while these foods are regularly consumed in Western countries, eating them for breakfast would seem strange and even unpleasant or aversive to many. As early as three years of age, children have been found to internalise their own cultural norms surrounding the appropriateness of certain foods at specific mealtimes (Birch, Billman, & Richards, 1984).

1.3.2. The antenatal period – development of food preferences in utero

Flavour exposure begins in the earliest stages of life; first in utero, via amniotic fluid, later through breast or formula milk and continuing following the introduction of solid foods. Evidence suggests these early experiences impact on later food preferences. Yet the extent to which specific flavour compounds from the mother's diet are transmitted during these pre- and early postnatal periods may vary within and between individuals. In comparison to findings with toddlers and older children, infants accept new flavours rapidly, with relatively few exposures required.

A child's first experience of flavour occurs long before they are introduced to solid foods and in fact the taste and olfactory systems are capable of detecting flavour information prior to birth (Schaal, Marlier, & Soussignan, 2000). Infants are first exposed to flavour through the amniotic fluid in utero and then later through breast milk (Mennella, 1995). Amniotic fluid transmits characteristics of a mother's diet to her infant, thus exposing the infant to varied early chemosensory experiences. There is some evidence to suggest that pre- and early postnatal flavour exposure may have rather different effects on food preference and acceptance than those seen in later childhood.

Human foetuses swallow a significant amount of amniotic fluid during gestation, especially at the latter stages (Pritchard, 1965) (roughly a litre per day at term) and flavours of foods eaten by mothers may be transmitted in this way. In the first experimental demonstration of the transmission of odorous compounds from a mother's diet to her amniotic fluid, the odour of garlic was detectable by a sensory panel of adults in the amniotic fluid of women who had ingested garlic capsules 45 minutes before an amniocentesis examination (Mennella, Johnson, & Beauchamp, 1995). It has also been demonstrated that garlic in amniotic fluid is detectable by foetuses. Hepper (1995) compared infants whose mothers regularly consumed foods containing garlic during the last part of their pregnancy to infants of mothers who did not. Between 15 and 24 hours after birth, infants of garlic-consuming mothers oriented their heads more towards a cotton swab containing garlic than those whose mothers had not consumed garlic. Similar results were forthcoming from a later study by Schaal et al. (2000) who compared behavioural measures of attraction to anise odour in infants whose mothers had or had not consumed anise flavour during pregnancy. Findings revealed infants of anise-consuming mothers preferred this odour at birth and four days later when compared with infants not exposed.

1.3.3. Infancy – development of food preferences during milk feeding

More recent experimental studies have provided stronger evidence of neonates responding to flavours in amniotic fluid and have shown that flavour learning continues after birth, during breast milk feeding.

1.3.3.1. Breastfeeding

Human milk, like amniotic fluid, is capable of transmitting characteristics of the mother's diet to her offspring. A study by Mennella and colleagues (Mennella, Jagnow, & Beauchamp, 2001) confirmed that exposure, either in utero or during breastfeeding, could influence food acceptance at the weaning stage (mean age: 5.7 months). Pregnant women who were planning to breastfeed were assigned to one of three groups: the first group drank carrot juice in the last trimester of their pregnancy and water only while breastfeeding, the second drank water in pregnancy and carrot juice during breastfeeding and a third group drank water during both periods. Results showed that babies born to mothers in the first and second groups displayed less negative expressions to carrot flavour at weaning than those in the third group. In addition, infants in the first group were perceived by their mothers to like the carrot flavour more and had a tendency to consume more, albeit non-significantly.

Forestell & Mennella (2007) found that at five to six months of age, breastfed infants reacted more positively than formula-fed babies to a novel fruit (peach) in terms of quantity eaten and speed of eating. In addition, a trained and blinded observer judged the infants' facial expressions, a measure of hedonic response in nonverbal infants (Rosenstein & Oster, 1988), while they ate the peaches and observed that breastfed infants displayed fewer negative facial responses compared to their formula-fed peers. The authors proposed this may have occurred because the breastfeeding mothers frequently consumed fruits during lactation. In contrast, there was no effect of breastfeeding on infants' responses to green beans. Since these same mothers fell far below recommendations for vegetable intake, these findings suggest that breastfeeding may only confer an advantage when mothers have regularly eaten similar tasting foods. Further experimental research supports the idea that breastfeeding is beneficial for later food acceptance. A study of five to seven month old infants in France and Germany founds those who had been breastfed ate significantly more of four unfamiliar foods than their formula-fed peers (Maier, Chabanet, Schaal, Leathwood, & Issanchou, 2008). While five to eight month old Danish breastfed infants also showed significantly greater acceptance of caraway flavour (d-Carvone), a far less intrinsically likeable flavour (Hausner, Nicklaus, Issanchou, Mølgaard, & Møller, 2010).

The reason for these differences in taste acceptance between breast and formula-fed infants is posited to result from the variety of flavours of the maternal diet transmitted through breast milk, as opposed to the uniform flavour of a commercial formula. The widely varying oral sensory experience that breastfed babies receive appears to better prepare them for novel flavours when the transition to solid foods commences. A recent study examined the impact of exclusive breastfeeding duration on flavour acceptance and found longer exclusive breastfeeding had a positive impact on infant's acceptance of umami (savoury) tastes (Schwartz, Chabanet, Laval, Issanchou, & Nicklaus, 2012).

Evidence has also emerged from observational studies to suggest there may be longer-term benefits of early feeding experiences, but it is by no means conclusive. In a UK study of 564 preschool children, parent-reported levels of fruit and vegetable consumption were higher among two to six year old children who had been breastfed compared to their formula-fed peers (Cooke et al., 2004). Skinner et al (2002) reported that 25% of the variance in variety of fruit consumed by a smaller sample of North American six to eight year olds (n=70) was predicted by duration of breastfeeding and early exposure to fruit. However other studies have failed to find an association between breastfeeding and later fruit and vegetable acceptance. In an Australian survey of 371 two to five year children no effect of breastfeeding was found on parent-reported food preferences (Russell & Worsley, 2007). More recently, findings from a prospective birth cohort of 3624 children in the Netherlands showed an association between longer exclusive breastfeeding and higher vegetable intake at aged five but no associations were found with fruit intake (Möller, de Hoog, van Eijsden, Gemke, & Vrijkotte, 2013). Elsewhere earlier cessation of breastfeeding has been found to relate to the number of non-core foods liked and tried by Australian two year olds (n=245) (Howard, Mallan, Byrne, Magarey, & Daniels, 2012). It is possible individual and cultural differences in maternal diets, as well as differences in sample characteristics and the kinds of first foods being introduced to infants may be contributing to these contradictory findings. However more research is needed if we are to understand the true effects of breastfeeding on children's food acceptance.

If breast milk acts as a vehicle for maternal dietary flavours, this may also contribute to cultural differences in the foods regarded as palatable by children. Cultural differences in food offered during weaning have been shown to contribute to food preferences later in infancy and childhood (Harris, 2008). In light of the experimental evidence of flavour transmission during pregnancy and breastfeeding, it is likely these effects of culturally specific flavour exposure begin even earlier (Forestell & Mennella, 2008; Mennella, Forestell, Morgan, & Beauchamp, 2009). Thus the inter-generational transmission of culturally determined taste preferences may be facilitated by early pre- and early postnatal flavour exposures.

Flavours known to be transmitted through breast milk include garlic (Mennella & Beauchamp, 1993b), ethanol (Mennella & Beauchamp, 1991), carrot (Mennella et al., 2001), vanilla (Mennella & Beauchamp, 1996b), mint and blue cheese (Mennella & Beauchamp, 1993a), and cigarettes (Mennella & Beauchamp, 1998), although there are likely to be many others. Recent work by Hausner and colleagues has demonstrated that there is not only variation between foods in the extent to which they are detectable in breast milk, but that there is also considerable variation between individuals in the timing and extent of the transfer of flavour compounds (Hausner, Bredie, Mølgaard, Petersen, & Møller, 2008). Hausner et al. (2009) investigated the flavour compounds in mothers' milk and concluded that while breast milk provides a variety of chemosensory experiences for the infant, the specific volatiles from the mother's diet are transferred selectively and in low quantities (Hausner et al., 2009).

1.3.3.2. Formula feeding

Formula-fed infants are typically fed only one brand of formula milk and thus are only exposed to a single uniform flavour until the introduction of complementary foods. However, while the limited flavour variety of formula milk may not facilitate infants' acceptance of novel food flavours, the specific taste of the brand of formula an infant is given may itself be preferred both in the short and longer-term. Exposure to different distinctively flavoured formulas in infancy has been shown to effect flavour preferences later in childhood. In a study by Mennella and Beauchamp (2002) the flavour variation inherent in three types of commercially available formula (milk, soy and hydrolysate) was exploited in order to determine whether later flavour preferences differed according to the type of formula-fed in infancy. As predicted, four to five year old children's' taste preferences varied as a function of the type of formula they had experienced earlier in life; children fed unpalatable, "off tasting" (Mennella, 1996) protein hydrolysate formula were more likely to prefer sour-flavoured juice while children fed soy formula as infants were more likely to prefer bitter tasting juices. Mennella and colleagues (2009) also investigated the impact of differing tasting formulas on four to nine month old infants' response to comparable tasting cereals at the introduction of solid foods. The infants who had been fed on hydrolysed casein formulas were found to eat significantly more of the bitter and savoury flavoured cereals, display fewer negative facial expressions while doing so and thus were judged to prefer them, when compared to breastfed and cow's milk-based formula-fed infants.

Research suggests the effect of exposure to specific formula flavours may also endure into adulthood. Formula milk in Germany was flavoured with vanilla for many years and in an opportunistic study of attendees at an environmental fair, 133 visitors were asked to complete questionnaires about their food preferences and habits, including a question asking whether they had been bottle- or breast fed as infants. They were subsequently asked to taste two types of tomato ketchup and to state which they preferred. Both ketchups were the same brand, but while one was pure ketchup, the second had 0.5 g of vanilla flavouring per 1 kg of ketchup added. The vanilla flavour was found to be barely detectable in a pre-test, yet of the bottle-fed individuals 67% preferred the vanilla flavoured ketchup compared with only 29% of those who had been breastfed (Haller, Rummel, Henneberg, Pollmer, & Koster, 1999).

These studies focussing on specific flavours of formula milk have also provided support for the concept of a sensitive period in flavour learning (Trabulsi & Mennella, 2012). Infants' acceptance of less palatable protein hydrolysate formulas vary according to the age at which they are introduced, as well as the absolute length of the exposure period. These formulas have been shown to be readily accepted by two month old infants when first introduced but rejected by seven month olds (Mennella & Beauchamp, 1996a). Early introduction to protein hydrolysate formulas in the first few months appears to impact on both immediate and longer-term acceptance of these flavours (Liem & Mennella, 2003; Mennella & Beauchamp, 2002; Mennella, Lukasewycz, Castor, & Beauchamp, 2011). These findings have been presented as evidence for increased plasticity in flavour programming during the first four to six months of life (Mennella et al., 2011; Trabulsi & Mennella, 2012), although there is little doubt that flavour preferences can continue to evolve throughout childhood and even into adulthood.

1.3.3.3. Additional factors effecting flavour exposure in infancy

The impact of flavour exposure on infants' acceptance, liking and consumption is not always clear, as demonstrated in an investigation of infants' acceptance of carrot flavour. This study investigated three to six month old breastfed infants' acceptance of carrot-flavoured or plain cereal, measured after a week during which their mothers consumed carrot juice or water (Mennella & Beauchamp, 1999). Infants whose mothers had consumed the carrot juice ate less of the carrot-flavoured cereal and spent less time feeding than did those whose mothers had drunk water. The authors suggested that this might be the result of the flavour becoming over familiar to infants who had been repeatedly and recently exposed to it (Rolls, Rowe, & Rolls, 1982b). Studies in both adults (Rolls, Rowe, & Rolls, 1982a) and children (Birch & Deysher, 1986) have shown that increased exposure to a food over an extended period (monotony) leads to decreased hedonic ratings of that food, whereas food eaten less recently may be considered more appealing. In adults, there is evidence that this can even occur for highly liked foods such as chocolate, although rating of blander foods such as bread seem more resistant to change (Hetherington, Pirie, & Nabb, 2002).

Studies demonstrating differences in the number of exposures required to effect a change in consumption at different ages might provide some insight into these apparently anomalous results. Generally speaking, studies of preschoolers (Wardle, Cooke, et al., 2003), school-aged children (Loewen & Pliner, 1999) and adults (Pliner, 1982; Pliner, Pelchat, & Grabski, 1993), suggest that between 10 and 20 exposures are needed to increase liking and that liking increases as a function of the number of exposures received (Birch & Marlin, 1982; Birch, McPhee, Shoba, Pirok, & Steinberg, 1987). In contrast, four to six month old infants' consumption and apparent liking rapidly increased after only one exposure in one study (Birch, Gunder, Grimm-Thomas, & Laing, 1998). As discussed already, it may be that the very early period up to six months is a sensitive phase for the introduction of varying flavours and that we are never again as open to new experiences or as willing to accept novel tastes. As a result, repeated exposure to the same flavour during this period may actually be counterproductive and to capitalise on this period of plasticity mothers should instead consume a varied diet in pregnancy and during breastfeeding. This is not to say that exposure to variety after the age of six months has no impact. Several studies have shown that despite the initial advantage conferred by breastfeeding, formula-fed infants exposed to greater flavour variety during the period of complimentary feeding are subsequently more accepting of novel foods when compared to infants repeatedly given the same food (Forestell & Mennella, 2007; Gerrish & Mennella, 2001).

It is clear that well before the initiation of complimentary feeding there is potential to introduce infants to a wide variety of flavours. Both amniotic fluid and breast milk are rich sources of chemosensory experience, and flavour exposure during these periods may impact upon lifelong food preferences. Flavour variety during periods of indirect flavour exposure, may improve long-term dietary outcomes.

1.3.4. Complementary feeding – the introduction of solids[4]

The introduction of solid foods into an infant's diet seems to be an important developmental event with the potential to influence food acceptance both in infancy and later in life. The period of infancy when solid food is first introduced, often referred to as weaning, may provide an unparalleled opportunity to directly and positively influence a child's long-term food preferences and diet. The term 'weaning' can be misleading in this context as it is sometimes interpreted as the cessation of breast or milk feeding. As a result the term 'complementary feeding' (CF) may be more useful since it conveys the message that the first foods are given in addition to, as opposed to instead of, the infants' milk diet. CF describes the transitional process that occurs between the period of exclusive breast or formula feeding and ultimately the consumption of family foods. This process often involves the introduction of purees and finger foods before moving onto 'lumpier' foods and foods that require chewing.

Research has shown that repeated direct exposure to a taste is particularly effective at increasing preferences in infancy. The earliest study investigating flavour exposure at the beginning of CF found increased acceptance of green beans or peas after 10 exposures (compared to pre-exposure) (Sullivan & Birch, 1994). Another study found eight exposures of bananas or peas led to large increases in infant's intake of these foods, compared to a control food, and noted significant increases after only one exposure. The effect was also found to extend to similar tasting foods within food groups (i.e. other fruits in the case of bananas and other sweet tasting vegetables in the case of peas) but not to different tasting foods (Birch et al., 1998).

[4] Some of the information provided in this section has been published in the following paper: Fildes, A. and Cooke, L. (2012). The munch bunch: healthy habits start at weaning. *Journal of Family Health Care 22,* 30-32.

The exposure effect has also been shown to work for foods that are initially refused. While previous research has indicated infants may increase their acceptance of some foods after a single exposure (Birch et al., 1998), Maier and colleagues found that initial rejection of a novel vegetable is not uncommon among six to ten month olds. Yet, after eight subsequent exposures to small tastes of this initially disliked vegetable, 70% of infants willingly ate it (Maier, Chabanet, Schaal, Issanchou, & Leathwood, 2007). Despite this, research has shown parents typically offer an initially rejected vegetable to their infant less than three-five times before giving up (Carruth, Ziegler, Gordon, & Barr, 2004; Maier, Chabanet, Schaal, Leathwood, & Issanchou, 2007). This suggests many infants are not receiving a sufficient number of exposures to increase their preferences for initially rejected flavours (such as vegetables). Instead it is likely parents are repeatedly offering children the foods they accept easily, potentially reinforcing and increasing liking for these already intrinsically liked foods (Nicklaus, 2011). Furthermore, a recent study exploring the introduction of vegetables during CF found mixing vegetables together into combined purees was a common practice in a sample of 75 UK mothers (Caton, Ahern, & Hetherington, 2011). This process could conceal the true tastes and textures of individual vegetables (i.e. masking the flavour of a bitter vegetable by combining it with something sweeter) and prevent the infant acquiring liking for distinct flavours.

A parent’s assessment of their child’s preference for a particular food is influenced by the infant’s facial responses when eating it (Forestell & Mennella, 2007). Parents might not persist in offering foods that elicit negative facial responses and instead serve sweet, easily accepted foods specifically because of a baby’s positive or negative facial expressions. Yet, an infant’s facial responses to foods do not necessarily correlate with their willingness to continue eating. It has been demonstrated that by concentrating on the infant’s willingness to eat, and persistently offering a small taste of a food on multiple occasions, both liking and intake can be enhanced, even for initially rejected foods (Forestell & Mennella, 2007; Maier, Chabanet, Schaal, Issanchou, et al., 2007).

While repeated exposure to a single flavour increases acceptance, a lack of variety risks sensory specific satiety or monotony. Sensory specific satiety refers to the temporary decline in satisfaction derived from the consumption of a certain type of food, relative to the renewal in appetite resulting from exposure to a new, unconsumed food. Daily changes in the vegetables offered to infants have been shown to lead to immediate increases in preference and intake and decreases in rejection of novel tastes (Gerrish & Mennella, 2001; Maier et al., 2008; Mennella, Nicklaus, Jagolino, &

Yourshaw, 2008). In addition, a more varied diet during the CF period has been linked to greater fruit and vegetable variety in childhood (Cooke et al., 2004; Skinner, Carruth, Bounds, et al., 2002). Gerrish and Mennella (2001) found that infants exposed to a variety of different vegetables, or carrots alone, over a period of nine days, significantly increased their intake of carrots compared with infants who were exclusively fed potatoes over the same period. In addition, the infants exposed to a variety of tastes ate more of a novel food, at the end of the nine day period compared with the groups fed potatoes or carrots (Gerrish & Mennella, 2001). A study by Maier et al. (2008) found that offering infants three vegetables, for three consecutive days each, did not significantly increase intake of new foods. However, daily changes in the vegetable offered did facilitate acceptance of unfamiliar foods, suggesting that the beneficial effect of variety is maximised by daily changes, and is not simply a function of the number of new vegetables being introduced (Maier et al., 2008).

As omnivores humans have adapted to eat a wide variety of foods. Perhaps infants are born with a drive for food and flavour variety which subsequently declines in response to repeatedly consuming the same foods time and again.

1.3.4.1. The timing of complementary feeding

The issue of when to introduce CF into an infant's diet has recently received considerable academic, press and public attention (Jonsdottir et al., 2012; Kramer & Kakuma, 2012; Michaelsen, Larnkjær, Lauritzen, & Mølgaard, 2010). A key reason to start CF is because milk alone is no longer sufficient to meet an infant's nutritional requirements (Reilly, Ashworth, & Wells, 2005; Reilly & Wells, 2005). However, because CF is also associated with an increased risk of bacterial infection, particularly in developing countries, and associations have been made between the introduction of solid foods and risk of allergies (Nwaru et al., 2010; Tarini, Carroll, Sox, & Christakis, 2006; Zutavern et al., 2008) and coeliac disease (Norris et al., 2005; Poole et al., 2006), recommendations on the timing of CF also take these factors into consideration (Schwartz, Scholtens, Lalanne, Weenen, & Nicklaus, 2011).

The current UK Department of Health guidelines recommend exclusive milk feeding for the first six months of life. Delaying the introduction of solids until six months is in line with the World Health Organisation (WHO) guidelines, based on the 2001 expert consultation report (World Health Organization, 2001) and WHO-commissioned systematic review (Kramer & Kakuma, 2002), and was adopted by the UK in 2003. Prior to this the WHO and UK Department of Health recommended introducing CF between four and six months of age. National recommendations for the introduction of solid foods vary between countries but range from between four and six months (e.g. Australia) to six months minimum (e.g. UK).

Much of the debate surrounding the timing of CF focuses on health issues such as specific food sensitizations, allergies, digestive health problems and increased risk of childhood obesity. While most researchers and health professionals agree that CF should not occur before four months because the infant's gastro-intestinal system is not ready to digest solid food before this age (Agostoni et al., 2008), the evidence for delaying CF until six months remains inconsistent and somewhat conflicting (Fewtrell et al., 2007). The timing of CF may also have behavioural consequences, specifically in terms of children's food acceptance and preferences. The idea of a sensitive period for flavour acceptance has been discussed previously in this chapter and may have further implications for the timing of solid food introduction.

A small study investigating the acceptance of salty versus plain cereals in 16-17 week old infants compared to 18 -25 week olds found acceptance of salty cereals was enhanced in the younger infants (Harris, Thomas, & Booth, 1990). There is also evidence for an effect of timing of fruit and vegetable introduction on later acceptance and preference: several cross-sectional studies have demonstrated a link between earlier exposure to fruit and future fruit consumption in preschoolers (Cooke et al., 2004) and school children (Skinner, Carruth, Bounds, et al., 2002). A small number of recent prospective studies have also investigated the timing of CF in relation to later food preference and intake. A birth cohort in the Netherlands (n=3624) reported increased fruit intake in five year old children introduced to solid foods prior to four months but no associations were found with vegetable intake (Möller et al., 2013). On the other hand, a prospective Australian study found earlier introduction of solids to relate to children liking a greater number of non-core foods at two years of age when the two factors were measured continuously (Howard et al., 2012). Similarly, animal studies have reported an increased preference for palatable and fatty foods in adult rats following earlier weaning (dos Santos Oliveira et al., 2011).

There is also evidence from the US suggesting early introduction to solid foods (before four months) is related to increased consumption of fatty or sugary foods at twelve months, after controlling for sociodemographic characteristics (Grummer-Strawn, Scanlon, & Fein, 2008) and an Australian longitudinal study reported that early introduction of solid foods (before 17 weeks) was related to introduction of non-core foods by 52 weeks of age (Koh, Scott, Oddy, Graham, & Binns, 2010). It could be that mothers who start CF early also introduce non-core foods and fruit earlier, potentially reinforcing innate preferences for sweet tastes, and resulting in increased liking for these foods. However, earlier CF may simply occur because an infant appears to be particularly hungry or food responsive.

The extent to which acceptance of other food types differs in relation to the age at which they are introduced remains unclear. Cooke et al. (2004) found an association between earlier vegetable introduction and increased intake in later childhood, although this association did not remain significant when adjusting for covariates (e.g. parental consumption and neophobia). Vegetables are intrinsically less liked than fruits as they are less sweet and mostly less energy-dense[5] and while they are readily accepted at the start of CF when infants are open to new tastes, by the time children are two years or older, many other factors may be influencing liking other than simply the timing of their introduction (Nicklaus, 2011).

In addition to tastes, the timing of introduction to textures, such as lumps, has been shown to be associated with later food acceptance. Research from the Avon Longitudinal Study of Parents and Children (ALSPAC) found that at seven years of age, children who had not been introduced to lumpy solids by nine months ate less of many food groups, including fruit and vegetables, and were reported as having significantly more feeding problems, compared to those introduced to lumpy foods earlier (Coulthard, Harris, & Emmett, 2009).

1.3.4.2. Baby-led weaning

In recent years the concept of 'baby-led weaning' (BLW) has garnered much popularity with mothers of young infants and received substantial press attention (Rapley & Murkett, 2008). BLW refers to a style of CF whereby infants are provided with solid finger foods and the emphasis is placed on infant self-feeding from the beginning, rather than traditional parental spoon feeding with purees. To date, very little scientific research has been conducted on the relative benefits of BLW. One recent study of 155 mother-infant pairs compared BLW infants to a spoon-fed control group and found some evidence of an increased preference for carbohydrates (including breads, cereals and potatoes) in infants in the BLW group, despite reports of less exposure to

[5] Increased caloric density has been posited as an attribute that increases liking for foodstuffs, energy density in relation to preference is discussed further in Chapter 2.

carbohydrate foods (Townsend & Pitchford, 2012). Indeed carbohydrates were the most preferred foods for the BLW group whereas the spoon-fed infants liked sweet foods most. However there was no difference between the weaning groups in preference scores for sweet foods (or any food groups other than carbohydrates) and vegetables were the least liked food for both groups of infants. The authors argue that the increased carbohydrate preference is indicative of more healthy food preferences as carbohydrates are the foods that ‘form the building blocks of healthy nutrition’ (Townsend & Pitchford, 2012). However, this assertion is somewhat confusing given the lack of evidence for either decreased carbohydrate preferences generally or a deficiency of carbohydrate foods in children’s diets currently. Furthermore these findings come from a single isolated study with few confounders measured and should thus be interpreted with caution. In reality many parents provide both purees and finger foods from early in the CF period and it might be more useful to consider this as a continuum rather than a dichotomy of feeding methods.

It has been reported that parents who adopt BLW believe it has multiple beneficial consequences, including; exposure to a variety of foods that encourages the development of a wider range of food preferences, resulting in a more varied diet later on (Brown & Lee, 2013) and encouraging generally healthier eating patterns and better appetite self-regulation (Cameron, Heath, & Taylor, 2012a). The assertion that BLW encourages greater acceptance of ‘healthier’ foods, including fruits and vegetables, due to more exposure to texture and flavour variety needs further exploration. As discussed, early exposure to a variety of flavours and textures has been shown to have beneficial effects on food acceptance; however it is yet to be conclusively shown that BLW results in more flavour or texture variety than traditional CF practices.

The advantages or disadvantages of BLW are confounded by factors such as SES, breastfeeding and the related issue of infants’ age at solid food introduction. BLW is inevitably related to later weaning because of a lack of developmental and physiological readiness in younger infants. It has been identified as the strongest predictor of delaying solid food introduction until six months of age (Moore, Milligan, & Goff, 2012). Research has also found mothers that adopt BLW are more likely to breastfeed and are more highly educated than mothers that use traditional CF practices (Brown & Lee, 2011). All these factors are themselves associated with variation in food preference and acceptance. A recent review of the evidence related to BLW concluded that a randomised controlled trial investigating this method of CF is urgently needed (Cameron, Heath, & Taylor, 2012b).

1.3.5. Early childhood

The effects of exposure on early preference learning have already been discussed in detail and exposure continues to be a key mechanism in the development of flavour preferences throughout childhood. There exists a considerable body of experimental research into the use of ‘mere exposure’ as a tool to modify children’s food preferences which will be discussed in more detail in Chapter 2. However, while there is some evidence of a generalisation effect of exposure on acceptance to other, similar foods in infancy, it appears that exposure in older children leads to greater acceptance only for the specific foods exposed (Cooke, 2007; Sullivan & Birch, 1990). In addition, the number of exposures needed to modify food preferences seems to increase with age (Birch, Anzman-Frasca, & Paul, 2012; Birch et al., 1998). This may in part result from the change in the strength of the ‘neophobic’ response that commonly starts at around two years of age (Cashdan, 1994; Cooke et al., 2007), manifesting as unwillingness to try new foods, as well as increased fussiness which may impact on food acceptance to the extent that more exposures are needed to modify preference.

1.3.5.1. Food fussiness, pickiness and neophobia

The rejection of novel or unfamiliar foods is known as ‘neophobia’ (Rozin, 1976). It is hypothesised that the avoidance of unfamiliar tastes is an adaptive strategy serving to protect a child from eating potentially toxic substances (Cooke, 2007; Rozin, 1976). Neophobia is relatively low in infancy but increases as the child becomes more mobile and capable of independently accessing and consuming potentially harmful substances. Typically, neophobia emerges at around two years of age and continues through the preschool years, gradually diminishing in later childhood (Cooke, 2007). Most research suggests that neophobia peaks between two and six years old (Birch et al., 1987; Cashdan, 1998; Koivisto & Sjödén, 1996; McFarlane & Pliner, 1997; Pelchat & Pliner, 1995; Pliner & Loewen, 1997).

There are significant adverse consequences of neophobia on food choice and preference in early childhood, particularly with regard to fruit and vegetable intake (Cooke, Carnell, & Wardle, 2006; Cooke, Wardle, & Gibson, 2003). Pliner developed a psychometric measure of neophobia; the Child Food Neophobia Scale (CFNS), and demonstrated that children with higher scores ate less fruit and vegetables but no less sweet, fatty or starchy foods than their lower scoring peers (Pliner, 1994). A recent study of two year old children found neophobia to be negatively related to the proportion of both vegetables and fruits liked by children, but no association was found with liking of non-core foods (Howard et al., 2012). Cashdan (1998) has suggested children's reluctance to try vegetables specifically, may be an adaptive response to the fact that plant toxins present a particularly significant poisoning risk. There is also evidence to suggest an association between neophobia and dietary variety in children. A study of eight year old children found that neophobia was positively related to the number of foods never tasted and the number of foods disliked, and negatively related to the number liked (Skinner, Carruth, Wendy, et al., 2002). These findings have recently been replicated in a sample of two to five year old Australian children where neophobia was associated with a decreased preference for all foods, but particularly vegetables, liking fewer food types, having fewer food preferences and a lower liking for healthy foods (Russell & Worsley, 2008).

The related, but nonetheless distinct construct of pickiness or food fussiness[6] has also been linked with reduced dietary variety and quality. While children with food neophobia are reluctant to eat new foods, picky children also resist eating many familiar foods and typically have a very narrow range of foods that they are prepared to eat. Little is known about the causes of fussiness and it is unclear whether unwillingness to eat a familiar food results from genuine dislike or from other social or behavioural factors (e.g. hypersensitivity to texture or touch). Neophobia and the rejection of familiar foods are strongly correlated (Potts & Wardle, 1998; Raudenbush, Van Der Klaauw, & Frank, 1995) and like neophobia, fussiness has been associated with an avoidance of vegetables in childhood (Galloway, Lee, & Birch, 2003).

Measures of picky or fussy eating are 'in their infancy' (Dovey, Staples, Gibson, & Halford, 2008) and little is known about the development of these behaviours over the lifespan (Carruth et al., 2004; Galloway et al., 2003). A cross-sectional survey found the proportion of American infants (n=3022) identified as 'picky eaters' by their caregivers increased from 19% among four month olds, to 50% for two year olds (Carruth et al., 2004). Recently, a small prospective study (n=120) explored the incidence, prevalence and persistence of picky eating in American children followed from two to eleven years (Mascola, Bryson, & Agras, 2010). Findings showed the incidence of picky eating was highest in early childhood, declining to very low levels by six years of age. It is possible that food fussiness follows a similar developmental course to neophobia, although the two constructs cannot easily be dissociated. However, it is also likely that as a child develops the ability to verbalise his/her dislikes, parental perceptions of common food rejections become stronger (Dovey et al., 2008).

[6] Pickiness and fussiness will be used interchangeably in this thesis to describe the same construct.

Fussy eating behaviours are certainly not restricted to very young children. A cohort study of German eight to twelve year olds (n=426) demonstrated picky eating to be a relatively common phenomenon among pre-adolescents (Jacobi, Schmitz, & Agras, 2008) . Moreover, while the majority of children in the previously mentioned prospective study of picky eating recovered within two years, many cases persisted much longer (Mascola et al., 2010).

A study exploring predictors of pickiness in seven year old girls found an association between increased pickiness and both shorter duration of breastfeeding and more limited variety in maternal vegetable intake. The author's concluded that pickiness, unlike neophobia, was predicted primarily by environmental or experiential factors that were subject to change (Galloway et al., 2003). An earlier comparable study investigating predictors of 'choosiness' in children's eating behaviour reported no associations between choosiness and either age or social class (Rydell, Dahl, & Sundelin, 1995). The disparity in findings from research into the associates of fussiness may in part result from the lack of a standard measure for this trait. Some previous studies have attempted to identify fussy children with a single item i.e. 'is your child a picky eater?' (Carruth et al., 2004) which is unlikely to accurately capture variation in this complex trait. Fussiness is a relatively new theoretical construct and while it is both theoretically and behaviourally distinct from neophobia, the two traits are clearly related and many picky children may also display neophobic traits (Dovey, Staples et al. 2008) which adds to the confusion in measuring and interpreting this behaviour.

Some people have suggested that pickiness may not be an entirely negative trait and by limiting the variety of foods a child will eat, excessive food fussiness or pickiness may protect against overweight (Galloway, Fiorito, Lee, & Birch, 2005). Negative associations between fussy eating behaviours and children's weight have been reported in the literature that support this argument (Carruth et al., 2004; Galloway et al., 2005; Jansen et al., 2012; Viana, Sinde, & Saxton, 2008; Webber, Hill, Saxton, Van Jaarsveld, & Wardle, 2009). However, numerous other studies have failed to find significant associations between weight and fussy eating behaviours among Swedish (Rydell et al., 1995; Svensson et al., 2011), Chilean (Santos et al., 2011), Dutch (Sleddens, Kremers, & Thijs, 2008), German (Jacobi et al., 2008) and American (Carruth et al., 1998) children. To date, the majority of research exploring pickiness and weight has been cross-sectional which may have contributed to these inconsistent findings. A recent exception comes from a Canadian longitudinal study of 1498 two to four year old children. In this study, children identified as 'picky eaters' at two or three years were less likely to be overweight, and more likely to be underweight, at four years, but as weight data were only available at the later time point, associations between fussiness and weight change were not explored (Dubois, Farmer, Girard, Peterson, & Tatone-Tokuda, 2007). A second longitudinal study in America examined the associations between pickiness and BMI in children aged two to eleven and reported no significant associations (Mascola et al., 2010), although the sample size in this second study was much smaller (n=120). Pickiness has also been associated with failure to thrive in children (Wright & Birks, 2000) and while pickiness may not be associated with health problems in the short-term (Rydell et al., 1995), less dietary variety, and specifically lower intake of vegetables, are themselves related to many longer-term negative health outcomes.

Breastfeeding has been linked with both lower neophobia and pickiness (Galloway et al., 2003) suggesting these traits are partially shaped by early taste exposure. Galloway et al. (2003) hypothesise that all children are born with a genetic propensity for neophobia, but that environmental and experiential factors determine whether a child develops into a ‘picky eater’. It is clearly necessary that neophobic reactions to unfamiliar foods are surmountable in order that children go on to eat a healthy and varied diet. Fortunately, while neophobia indicates that novel foods will often be initially rejected, it is not a fixed trait and both preference and acceptance of unfamiliar foods appear to be modifiable throughout childhood (Birch, 1998a; Cooke, 2007).

1.3.6. Other preference learning mechanisms

1.3.6.1. Modelling

Rozin and Kennel (1983) observed that instances of acquired preferences for innately aversive flavours (such as chili pepper) occur exclusively in humans, or animals with close relationships to humans, and suggest social factors play a key role in overcoming these aversions. Beyond the mechanism of overcoming natural aversions, evidence suggests social factors play a role in shaping an individual’s unique pattern of taste preferences. Children naturally learn through imitation and it is this kind of observational learning that forms the basis for Bandura’s social learning theory. This suggests that by watching others perform a behaviour or action, we learn how to do it ourselves and are able to observe the likely consequences (Bandura, 1998).

In early childhood it is parents, siblings and to some degree peers who are most influential in a child’s development and can act as role models to encourage the tasting of both novel and familiar foods (Addessi, Galloway, Visalberghi, & Birch, 2005; Benton, 2004; Gibson et al., 2012). By demonstrating tasting a food themselves and making exaggerated 'yummy' noises and facial expressions during mealtimes, parents are instinctively using modelling to encourage their young children to eat and it appears to be highly effective. One study showed toddlers will taste a food more readily when they have observed their mother eating it than when a stranger models the eating behaviour (Harper & Sanders, 1975). This suggests that modelling may help explain the strong parent-child correlations observed for food preferences (Coulthard & Blissett, 2009; Howard et al., 2012). However studies examining the effect of within-family modelling on preferences are necessarily confounded by other factors such as food availability, exposure and shared genes.

Although modelling is another potential way to encourage liking for healthier foods (Benton, 2004; Hendy & Raudenbush, 2000), negative effects are also possible. The modelling of unhealthy eating habits by parents or peers could result in decreased liking for nutritious foods and increased preference for energy-dense foods. Evidence suggests peers can influence acceptance or rejection of new foods, the latter being particularly difficult to reverse in young children (Greenhalgh et al., 2009).

1.3.6.2. Conditioned flavour aversions

As well as learning to like foods, children can also learn dislikes when they experience digestive disturbances, post ingestion. Conditioned taste aversions result from a rapidly-learned association between a specific flavour and negative gastro-intestinal consequences such as nausea or vomiting, when the two occur in succession (though the two events may not in reality be connected) (Garcia, Ervin, & Koelling, 1966). Once a conditioned food aversion has been established, it is not easily reversed and may persist for many years. Conditioned flavour aversions occur more frequently in children, possibly because they are formed most readily for unfamiliar foods (McFarlane & Pliner, 1997; Wardle & Cooke, 2008).

1.3.6.3. Flavour-nutrient learning

Together with sweet tasting foods, fatty and energy-dense foodstuffs (such as pizza and chips) are among those most liked by children (Birch, McPhee, Steinberg, & Sullivan, 1990; Cooke & Wardle, 2005; Johnson, McPhee, & Birch, 1991; Skinner, Carruth, Wendy, et al., 2002). Attempts to understand how preferences for energy-dense foods develop have largely focussed on classical conditioning-based learning paradigms. In these models it is hypothesised that an association is formed between the sensory properties i.e. flavour and texture, of a food (the conditioned stimulus) and its post-ingestive consequences i.e. a pleasant sensation of fullness, (the unconditioned stimulus). In circumstances where food sources are scarce, it is adaptive to develop preferences for energy-rich foods, but in the current obesogenic environment these preferences have obvious negative repercussions.

One widely recognised learning model, flavour–nutrient learning (FNL), is considered by many to be a key driver of acquired flavour preferences (Rozin & Zellner, 1985; Yeomans, 2012). FNL occurs when an individual develops a liking for a food through associating the flavour (the unconditioned stimulus) with the positive consequences of nutrient ingestion (the unconditioned stimulus) (Rozin & Zellner, 1985) If adverse post-ingestive consequences can give rise to negative preferences (as with conditioned taste aversions), it follows that acquired positive preferences are a likely consequence of consuming energy-dense foods (Yeomans, 2012). FNL may help explain why although vegetables in general are among children’s most disliked foods, the energy density of individual vegetables is predictive of children’s liking and consumption (Gibson & Wardle, 2003).

FNL has been evaluated by researchers in experimental studies aimed at increasing children’s preference for novel or disliked flavours, in which a flavour is consistently presented in an energy-dense form (e.g., by adding macronutrients) (Caton et al., 2012; A. Jansen & Tenney, 2001; Johnson et al., 1991; Kern, McPhee, Fisher, Johnson, & Birch, 1993; Zeinstra, Koelen, Kok, & de Graaf, 2009). FNL experiments require that the incorporation of additional nutrients (or energy) into a food is not obvious to participants. This is achieved by disguising any changes in the sensory quality (i.e. flavour) generated by the nutrient addition (Yeomans, 2012) so FNL studies commonly add substances such as maltodextrin, canola oil or sucrose to foods to increase energy content. However, findings have been inconsistent and whether FNL can be used to increase children's liking of the taste of vegetables remains to be established. Experimental studies incorporating FNL techniques are described in more detail in Chapter 2 of this thesis.

1.3.6.4. Flavour-flavour learning

A second flavour conditioning procedure, flavour-flavour learning (FFL) has been proposed as an alternative mechanism for overcoming dislike for a specific taste (Havermans & Jansen, 2007; Zellner, Rozin, Aron, & Kulish, 1983). FFL occurs when a novel or disliked flavour (the conditioned stimulus) is paired with an already familiar and liked flavour (the unconditioned stimulus), leading to an association between the two flavours, and in theory, resulting in an increase in preference for the novel flavour, even when subsequently presented unpaired (Havermans & Jansen, 2007). FFL has also received some attention as a potentially useful tool in the promotion of vegetable liking and intake in children, further details of which will also be provided in Chapter 2.

1.3.7. Correlates of food preference and intake in childhood

A body of literature exists around factors associated with food acceptance (intake and/or liking) in childhood, particularly for fruit and vegetables. However the majority of research to date has focussed on factors related to 'intake' rather than 'liking' and few of these studies involved preschool-aged children. Measures of daily intake and reported liking both have their own advantages and disadvantages as methods for assessing food acceptance. Daily intake is arguably the more objective measure; however it is potentially confounded by availability and short-term fluctuations in dietary patterns and thus may be a less reliable measure of past and future food acceptance.

1.3.7.1. Sociodemographic correlates

A number of previous studies have explored sex differences in food acceptance, particularly for fruits and vegetables. In one cohort study of 289, eight to fourteen year olds developmental trends in intake and eating patterns were found to be similar for both sexes (Lytle, Seifert, Greenstein, & McGovern, 2000) and a second study of 3534 young Spanish people (aged two to twenty four years) similarly reported few sex differences (Perez-Rodrigo, Ribas, Serra-Majem, & Aranceta, 2003). Research involving Australian preschool children (n=371) found no significant sex differences for a number of food preferences although the authors report a higher liking for vegetables in girls than boys that approached significance (Russell & Worsley, 2007). A British study similarly reported greater preferences for vegetables in girls compared to boys among four to five year olds (n=428) (Wardle, Sanderson, Gibson, & Rapoport, 2001) and comparable findings of an increased intake of vegetables and/or fruits have been reported in American (n=1481) (Reynolds et al., 1999) and Norwegian (n=885) (Lien et al., 2001) children and adolescents. Another British study reported gender differences in preferences for multiple foods among 1232 four to sixteen year olds; with girls displaying increased liking for fruit and vegetables; while boys liked fatty and sugary foods, meat and eggs more than girls (Cooke & Wardle, 2005). Higher liking for fatty or sugary foods among boys has also been reported among 366 British seven to nine year olds (Hill, Wardle, & Cooke, 2009). Taken together, these studies suggest a trend towards increased acceptance of fruits and vegetables in girls compared to boys but the findings are not entirely consistent and support for gender differences in liking and intake of other food groups is limited.

Measures of socioeconomic status have been associated with differences in food acceptance with studies reporting a relationship between maternal education and consumption of vegetables in two to six year old children (Cooke et al., 2004) and intake of both fruit and vegetables in seven year olds (Jones, Steer, Rogers, & Emmett, 2010). Pearson, Biddle, and Gorely (2009) similarly reported positive associations between parental occupation and fruit intake and between parental education and fruit and vegetable intake in adolescents. However several studies looking at food liking, rather than intake, have found no association between parental education or other indicators of social class and food preferences in ten-fourteen year boys (Diehl, 1999) or two to five year old boys and girls (Russell & Worsley, 2007).

1.3.7.2. Parental dietary correlates

Parental food intake has been consistently associated with children's eating patterns, particularly for fruit and vegetable intake (Cooke et al., 2004; McGowan, Croker, Wardle, & Cooke, 2012; Pearson et al., 2009; Rasmussen et al., 2006). A meta-analysis examining the relationship between parent and child food preferences reported a significant but small correlation for both mothers and fathers (Borah-Giddens & Falciglia, 1993). More recently an Australian study showed maternal preferences were highly correlated with toddler preferences among 245 two year olds (Howard et al., 2012).

1.3.7.3. Anthropometric correlates

Several studies have investigated the relationship between child weight and food preferences, primarily to identify whether increased liking for sweet, fatty or energy-dense foods, or conversely decreased liking for 'healthy' nutrient-rich foods, are associated with overweight in childhood. However, these studies have been cross-sectional in design preventing conclusions about causation and the findings have been mixed. Two studies have reported a cross-sectional association between high-fat food preference and triceps skinfold measurements, one in a small sample of three to five year olds (n=18) (Fisher & Birch, 1995) and another in a larger sample of nine to twelve year olds (n=88) (Ricketts, 1997). Similarly, fat and sweet taste preferences have been positively associated with overweight and obesity in six to nine year old children from throughout Europe (n=1696) (Lanfer et al., 2012). A study involving four to five year old

UK twins (n=428) used parental BMI as an indicator of child obesity risk, and reported children of heavier parents displayed increased liking for high-fat foods as well as a decreased liking for vegetables (Wardle, Guthrie, Sanderson, Birch, & Plomin, 2001). Mirroring this finding, higher liking for both fruits and vegetable was found to associate with lower risk of overweight among ten to eleven year old black American children (Lakkakula, Zanovec, Silverman, Murphy, & Tuuri, 2008). A number of other studies have reported no significant relationship between child adiposity and preferences, either for fatty and sugary foods (Diehl, 1999; Fieldstone, Zipf, Schwartz, & Berntson, 1997; Hill et al., 2009) or for fruits and vegetables (Diehl, 1999; Hill et al., 2009).

1.3.7.4. Child appetitive correlates

Aspects of the child themselves, such as their eating or appetitive behaviours, have been highlighted as correlates of food acceptance. As discussed previously, neophobia and food fussiness have been associated with decreased acceptance of foods generally, but especially with lower preferences (and intake) for fruits and vegetables (Cooke et al., 2004; Galloway et al., 2003; Howard et al., 2012; Jacobi, Agras, Bryson, & Hammer, 2003). Other appetitive characteristics have received little attention in relation to children’s food preferences or intake. One exception is ‘enjoyment of food’, as measured by the Child Eating Behaviour Questionnaire (Wardle, Guthrie, Sanderson, & Rapoport, 2001), which has been linked with higher intakes of both fruit and vegetables (Cooke et al., 2004).

While many potential predictors or correlates of children’s food acceptance have been identified in the literature, the equivocal nature of existing findings, and the lack of focus on preferences specifically, highlights the need for further research in this area.[7]

1.4. Genetic influences on the development of food preferences

1.4.1. Innate taste preferences

Humans can learn to eat virtually anything, but certain types of food are almost universally liked from the outset and these preferences seem to transcend cultural variations. Children may be generally more accepting of foods in early infancy,

---

[7] The literature reviewed in this chapter, relating to factors associated with children’s food acceptance (both intake and liking), has been summarised in a table and is available to view in Appendix 2.1

however, even very young infants show an apparent preference for certain foods, such as sweet tasting fruits in comparison to others, such as bitter green vegetables. These innate preferences are likely genetically determined. Through examining facial expressions, researchers have demonstrated that new born infants show more positive facial responses to sugar solutions in comparison to water (Beauchamp & Moran, 1982; Maller & Desor, 1973) and more negative facial responses to sour and bitter tastes (Desor, Maller, & Andrews, 1975; Steiner, 1979). This innate response to bitter or sour flavour is illustrated in Figure 1.2 showing a one week old infant's facial responses to lemon juice. In contrast, preferences for salt does not appear to be present at birth, instead developing through environmental exposure and becoming observable in infants from around four months of age (Beauchamp, Cowart, & Moran, 1986; Harris et al., 1990).

Figure 1.2: Facial responses to lemon juice in a one week old infant

1.4.2. The genetic contribution to individual variation in taste preferences

Although greater liking for sweet tastes and decreased preference for bitter tastes appears to be innate and universal, humans vary in their ability to perceive, and the extent which they prefer these qualities. These individual differences probably arise due to a combination of experience (such as early life exposure as discussed previously) and perceptual differences arising from genetic variation (Reed, Tanaka, & McDaniel, 2006). Individual differences in taste preferences arising from genetic variation have been investigated in two ways; from the 'bottom-up' (from biology to behaviour) and from the 'top down' (behaviour to biology) (Breen et al., 2006). 'Bottom-up' research has focussed on categories of taste preference such as 'sweet' or 'sour' and the heritability of sensitivity to specific compounds, including how this relates to preferences for specific foods. Whereas the 'top down' approach involves heritability studies using biologically related individuals to determine the relative contribution of genes in taste perception and preference

1.4.2.1. The biological basis for a genetic contribution to taste preferences; PROP sensitivity and sweet sensitivity

Little is known about the genetic aspects of taste perception, with the exception of the bitter compound Phenylthiocarbamide (PTC) and the related compound 6-propyl-2-thiouracil (PROP) (which has lower toxicity). These thioureas compounds are tasteless to some people but extremely bitter to others. It has been estimated that approximately 70% of the white population of Western Europe and USA perceive these compounds to be moderately to intensely bitter (this group has been labelled 'tasters') and of these 70%, a small subgroup are highly sensitive to the taste (labelled 'supertasters'). The remaining 30% perceive thioureas as only mildly bitter or completely without taste (Tepper, 1999).

Adult PTC and PROP tasters have been shown to dislike very sweet or bitter foods more than non-tasters (Bartoshuk, 1979; Tepper & Nurse, 1997), be more sensitive than non-tasters to bitterness and sourness (Prescott, Soo, Campbell, & Roberts, 2004) and in some studies to show decreased liking for bitter citrus fruits and cruciferous vegetables (Drewnowski, Henderson, Hann, Berg, & Ruffin, 2000; Drewnowski, Henderson, Levine, & Hann, 1999; Kaminski, Henderson, & Drewnowski, 2000). In children, PROP sensitivity has also been associated with lower acceptance and intake of some bitter tasting vegetables in a laboratory setting (Bell & Tepper, 2006; Keller, Steinmann, Nurse, & Tepper, 2002) but not with parent-reported vegetable intake, where no difference was observed between tasters and non-tasters (Keller et al., 2002; Keller & Tepper, 2004).

It is relatively easy to measure heritability for these compounds because differences among individuals are large and polymorphisms in a single gene (TAS2R38) have been determined to account for most of the variation among individuals (Kim et al., 2003). The TAS2R38 gene has two common alleles, with the allele for tasting mostly dominant over the allele for non-tasting. However, twin studies and molecular genotyping have indicated that there are other genes or environmental factors also contributing to the perception of these compounds (Hansen, Reed, Wright, Martin, & Breslin, 2006; Martin, 1975; Sharma, 2008; Tepper, 2008). As a result, there is a continuous range of variation in tasting, not an absolute separation between tasters, non-tasters and supertasters. The genetic contribution to other taste qualities has been comparatively more difficult to characterise due to either the polygenic nature of these traits or interactions between genes and the environment.

1.4.2.2. Evidence for the heritability of food preferences and neophobia

Behavioural genetic designs offer useful methodologies for researching the development of children's food preferences and eating patterns (Faith, 2005). By examining similarities in ratings of intensity and preference for different tastes between biologically related family members, it is possible to determine the extent to which these traits are genetically determined. Family and twin studies provide a measure of 'heritability', which refers to the proportion of similarity in a trait between two family members that is due to their shared genetic variation. The study of the heritability of taste perception and preference has received very little attention compared to other sensory systems (Reed et al., 2006), although there has been slightly more focus on the heritability of the related construct of food neophobia (Cooke et al., 2007; Johnson et al., 1991; Knaapila et al., 2011).

Family studies are useful in providing an indication of 'familiality' for a given trait, (i.e. taste preferences) but the design is limited as positive correlations can be due to both genetic effects and those of the shared family environment. In comparison, twin designs are particularly useful in taste preference research because similarities are compared between twins who are genetically identical (monozygotic; MZ) and twins who are only as genetically similar as any singleton siblings and share on average 50% of their genes (dizygotic; DZ). Because both MZ and DZ twins usually share very similar early food environments (including in utero and commonly during milk feeding) any differences in correlations of taste preferences among MZ and DZ twins are assumed to result from genetic differences.

1.4.2.2.1. Family studies

Familial correlations in food preferences, for both individual foods and food groups, have received limited attention, especially in childhood (Reed, Bachmanov, Beauchamp, Tordoff, & Price, 1997). Pliner and Pelchat (1986) examined associations in food preferences between two to seven year old children and their parents and siblings. Children's food preferences were correlated with those of both their parents, and more so with their nearest-age siblings. Likewise, a study measuring sweet taste preferences among four to five year old Brazilian children and their mothers found a small but significant correlation between mothers and children (Maciel, Marcenes, Watt, & Sheiham, 2001). On the other hand, several studies of family resemblance for individual food items have demonstrated no familial associations. Birch (1980) found correlations between preschool children and their parents on liking of fruits, vegetables, sandwiches, and snacks to be no higher than correlations between the children and other non-related adults. Similarly a second study found no significant correlation between preschoolers' food preferences and those of their families (Ritchey & Olson, 1983).

There is some evidence from family studies suggesting a genetic contribution to neophobia. Significant correlations between parents and children on measures of neophobia have been found for; five to eleven year olds (Pliner & Loewen, 1997), seven year olds (Galloway et al., 2003) and nine to eleven year olds (Falciglia, Pabst, Couch, & Goody, 2004). On the other hand, a Swedish study found only limited evidence for an association between parent and child neophobia in two to seventeen year olds, although significant correlations were found for some individual scale items (Koivisto & Sjödén, 1996).

It appears there is some evidence of a familial aggregation of both food preferences and neophobia however correlations are often low and the results are sometimes inconsistent. These inconsistencies may in part reflect the fact that taste preferences and neophobia change over the life span (e.g., Beauchamp and Cowart, 1987). Furthermore, the relative influence of genes and the environment on these traits may change across the lifespan. This is a problem when comparing parents and children or even similarly aged siblings. Developmentally dependent expression of these phenotypes can confuse the study of genetic influences when individuals of different ages are compared, and thus the study of parent-child correlations may be not be the best way to examine genetic effects. In addition, correlations between parents and children (or between siblings) may suggest shared genes *or* shared environments because the two are confounded. Correlations between mothers and fathers would provide evidence of a shared environment effect because parents are not biologically related (assuming that 'assortative mating'[8] does not occur), and such associations

[8] 'Assortative mating' refers to individuals choosing mates that are similar to themselves on genetically-determined traits, raising the possibility that unrelated spouses may have some genes in common.

have sometimes been observed for food preferences (Logue, Logue, Uzzo, McCarty, & Smith, 1988; Rozin, 1991). In addition, associations between siblings are often higher than those between parents and children (Pliner & Pelchat, 1986), which might suggest that environmental factors are influencing trait similarities, since siblings have more environmental factors in common. Further complicating this issue are findings of correlations between parents and children but not between siblings (Pliner & Loewen, 1997), which might indicate influences of differences in rearing, early development or uterine experiences.

1.4.2.2.2. Twin studies

There have been very few twin studies investigating the heritability of food preferences, particularly among children. Some investigations using the twin design found evidence of genetic influences on certain food preferences, although estimates appear to depend upon the type of food examined and again results have varied. Early twin investigations into the heritability of food preferences focused on a limited variety of individual foods that varied from study to study. In one such analysis, 35 twin pairs aged nine to eighteen years rated their liking of 17 foods following a taste test. Significant differences in the intra-pair correlations were found for only six of the 17 foods. The foods for which liking was found to be partly heritable were; orange juice, broccoli, cottage cheese, chicken, sweetened cereal and hamburger (Falciglia & Norton, 1994). Similarly, an adult twin study found evidence for some heritability of liking for eight of 24 individual foods examined, which also included orange juice and broccoli, as well as grapefruit juice, apple juice, strawberries, green beans and bacon (Krondl, Coleman, Wade, & Milner, 1983). In these two studies the effects of the environment were more important than genes in the determination of food preferences. Whereas three other studies using the twin design have found no evidence for a genetic component to food preferences in either children (Greene, Desor, & Maller, 1975) or adults (Fabsitz, Garrison, Feinleib, & Hjortland, 1978; Faust, 1974). However, all of these early studies were limited due to small sample sizes, and confidence intervals were generally not reported; making it likely that null findings resulted from limited power to detect anything other than very large genetic effects.

More recently, a study involving 214 twin pairs from the Twins Early Development Study (TEDS) estimated the heritability of food group preferences in four to five year olds. Parents reported on their children’s liking of 77 different foods, which were then grouped into four categories (based on a factor analysis) (Breen et al., 2006). The heritability estimates, i.e. the percentage of the variance in the preference determined by genetic factors, differed for each food group type; 20% for desserts, 37% for vegetables, 51% for fruits, and 78% for protein foods. Accordingly, shared environmental effects were 64% for desserts, 34% for fruits, 51% for vegetables, and 12% for proteins, suggesting that shared environmental factors (i.e. exposure and social influences) also influence liking for those foods in young children. The same study also found that MZ correlations were significantly higher than DZ correlations for 72 of the individual foods, indicating a heritable basis to preference for most foods (Breen et al., 2006). Although this is the largest twin study yet reported to investigate heritability of children's food preferences, the genetic and environment estimates all had wide confidence intervals indicating the need for replication in larger samples.

In contrast the genetic influence on neophobia is strong and has been clearly demonstrated through the twin design. The TEDS sample was also used to assess the heritability of neophobia using a parent-report questionnaire (n=5390) when the twins were slightly older (nine to eleven years). Neophobia was found to be 78% heritable with the remaining variance accounted for by non-shared environmental effects (22%), and no evidence for any shared environment effects (Cooke et al., 2007). Recently, a smaller study (n=132) explored the heritability of neophobia in four to seven year old twins and reported similar findings, with genetic influences on neophobia estimated at 72% and the remaining contribution explained by non-shared environmental factors (Faith, Heo, Keller, & Pietrobelli, 2013).

Neophobia is considered a stable trait (Pliner & Hobden, 1992) and has also been linked with personality characteristics such as 'emotionality' (Pliner & Loewen, 1997) and 'anxiety' (Pliner & Hobden, 1992), which are themselves partly influenced by genes (Eid, Riemann, Angleitner, & Borkenau, 2003; Legrand, McGue, & Iacono, 1999). Neophobia has also been shown to correlate negatively with 'openness', novelty seeking and excitement-related dimensions (Knaapila et al., 2011; Pliner & Hobden, 1992). It may therefore be influenced by genes that do not only determine an individual's approach to new foods but also contribute to vigilance or novelty seeking more generally. In contrast the link between the related trait of pickiness and personality or dispositional traits is less clear (Galloway et al., 2003), although one study has suggested a small association between pickiness and negative affect (Jacobi et al., 2003). These findings have led to the suggestion that pickiness is primarily influenced by environmental factors whereas neophobia is predicted by more enduring, dispositional or genetic factors (Galloway et al., 2003). However, no studies directly investigating the relative genetic and environmental influences on pickiness or food fussiness have yet been undertaken.

Only a handful of studies have ever attempted to explore the relative influences of genes and the environment on food preferences in early childhood and the findings of these studies have varied, perhaps due to disparate methods and limited sample sizes. It would seem, unlike other eating-related behaviour traits that have been measured, heritability for food preferences is not particularly strong. Early reviews on heritability of food preferences concluded that environmental influences play a much more significant role in shaping these characteristics than genetic factors, but that genes are nonetheless involved to some degree (Perusse & Bouchard, 1994; Reed et al., 1997). It is logical that there be considerable room for environmental influence on food preferences given the evolutionary need for human beings to eat a range of foods, and adapt their tastes in line with availability. Rozin (1976) pointed out that it is characteristic for omnivores to have few biological predispositions governing food choice, and those that do exist seem to influence general flavour preferences, such as the universal liking for sweet tastes.

1.5. Summary

Furthering understanding of how food preferences develop in childhood is critical, if strategies to reverse escalating trends in unhealthy dietary patterns are to be devised, and public health improved globally. This chapter has described the complex and multifaceted nature of food preferences and highlighted evidence identifying factors that influence these traits, as well as exposing gaps in the existing literature. Figure 1.1 illustrates how environmental and genetic influences are thought to combine to shape a child's individual pattern of taste preferences. While the importance of many early environmental influences, specifically flavour exposure, has been well-documented the genetic contribution to the development of food preferences remains unclear.

CHAPTER 2 . THE MODIFICATION OF FOOD PREFERENCES: REVIEW OF THE LITERATURE

As preferences are strongly predictive of intake, modifying preference or acceptance of foods would likely impact on the quantity consumed, or frequency with which they are eaten. There has been considerable interest in identifying and developing effective strategies for modifying food preferences in children, especially with the aim of increasing liking and intake of fruits and vegetables. Early interventions to increase fruit and vegetable intake are likely to maximise health benefits both in the short and longer-term, and may establish lasting healthy habits as eating behaviours in childhood are highly predictive of those in later life (Cusatis et al., 2000; Kelder, Perry, Klepp, & Lytle, 1994; Singer, Moore, Garrahie, & Ellison, 1995). Considerable attention has focussed on targeting school-aged children and young people. Schools are popular settings for intervention studies as they provide the opportunity to target large numbers of children simultaneously. However the success of interventions aimed at increasing fruit and vegetable intake in schoolchildren has often been limited (Parker & Fox, 2001; Perry et al., 1998) particularly for vegetables (Anderson et al., 2005; Delgado-Noguera, Tort, Martinez-Zapata, & Bonfill, 2011; Evans, Christian, Cleghorn, Greenwood, & Cade, 2012). A systematic review of population-based interventions with schoolchildren found even though many of the programs were extensive and multi-component, five out of the 15 studies reviewed reported no significant increases in fruit and vegetables consumption, and in those that did achieve an increase this typically equated to less than one serving per day (Knai, Pomerleau, Lock, & McKee, 2006). A second European review of school-based interventions also concluded that positive effects, when they occur, are generally small and disappointing given the intensity of the interventions (Van Cauwenberghe et al., 2010).

Interventions targeting preschool children and infants are comparatively few despite the evidence that eating patterns and preferences may be more malleable in younger children. However early childhood health interventions represent a rapidly growing field of research and recently there have been several studies attempting to redress the balance (Hesketh & Campbell, 2010). As this thesis focusses on the development and modification of food preferences in early childhood, this section will only include interventions targeting children under five.

2.1. Multi-component interventions targeting children under five

2.1.1 Preschool children

No multi-component interventions reporting fruit and/or vegetable *liking* as an outcome measure could be identified in preschool children. Instead six studies that aimed to increase preschool children's fruit and vegetable *intake* are described below.

The Beastly Healthy at School was a randomised control trial aiming to increase fruit and vegetable consumption in the preschool setting in Belgium. The multi-component intervention incorporated child education, parent and teacher education, parent modelling and increased fruit and vegetable availability. Fruit and vegetable intake was assessed using a parent-reported Food Frequency Questionnaire at a six month follow-up for 308 and 168 children allocated to intervention and control preschools respectively. The intervention had no effect on vegetable consumption, although a small but significant impact on child fruit consumption was reported (Vereecken et al., 2009). Children attending intervention preschools increased their daily fruit intake by 6 grams from baseline to the six month follow-up, while fruit consumption among children in control preschools reduced by 4 grams over the same period. The authors suggest that the increase in fruit intake was primarily due to fruit being made available in intervention schools (Vereecken et al., 2009), implying that simply improving availability may be sufficient to increase fruit, but not vegetable, intake. However, it should be noted that the increases in fruit consumption observed in the intervention group, while statistically significant were extremely small (6 grams) equating to a fraction of a portion per day.

High 5 for Kids (H5-KIDS) was a North American intervention designed to increase fruit and vegetable intake in two to five year old disadvantaged children (Haire-Joshu et al., 2008). Participants were 1306 children and their parents participating in the 'Parents As Teachers' national parental education programme. The parent education-based intervention focussed on parental knowledge and modelling of fruit and vegetable intake, non-coercive feeding practices and fruit and vegetable availability, and involved home visits with additional print and audio-materials. Child fruit and vegetable intake was assessed via telephone using a Food Frequency Questionnaire six to eleven months after baseline. No significant effect of the intervention was found in intake of fruits or vegetables, although the authors did report a significant positive intervention effect for combined fruit and vegetable consumption (of up to one third of a serving) in a subgroup analysis of healthy weight (relative to overweight) children (Haire-Joshu et al., 2008).

A recent study in German preschools used a combination of parental education and theory-based learning mechanisms in a nutritional intervention involving 348 three to six year old children (De Bock, Breitenstein, & Fischer, 2012). Nutrition experts delivered the intervention once weekly over a six month period, during 15 two-hour sessions, five of which actively involved parents. Intervention activities consisted of; familiarizing with different food types, cooking and eating meals together, modelling by parents, play acting modelling with dolls and repeated weekly exposure through the offering of healthy snacks. Parent-report questionnaire measures of fruit and vegetable intake were collected six and twelve months post-intervention. The study found a significant small intervention effect on both fruit and vegetable intakes, amounting to around 0·23 and 0·15 daily portions (a portion was described as ‘the size of a child's hand’ and represented about 100 g), respectively.

The ‘Healthy Habits’ cluster randomised controlled trial aimed to assess the efficacy of a telephone-based intervention, delivered to parents to increase their three to five year old children’s fruit and vegetable consumption (Wyse et al., 2012). Parents of young children (n=394) were recruited through preschools in New South Wales, Australia. Parents allocated to the intervention condition were given printed resources and received four 30-minute telephone calls targeting aspects of the home environment such as; increasing fruit and vegetable availability and accessibility in the home, increasing parental modelling of fruit and vegetable consumption and eating dinner as a family. The control families received generic printed nutrition information. Children's fruit and vegetable intake were assessed at baseline and at two and six month follow-ups using a parent-reported food frequency questionnaire. Significantly higher combined fruit and vegetable intake scores were reported for the intervention children compared to the control children at two months and six months post-intervention. However, a sensitivity analysis which imputed missing data rendered the intervention effect non-significant at the six month follow-up. The effects of the intervention separately for fruit and vegetable intake are not reported. It is also of note that according to the measurement tool used in this study, baseline fruit and vegetable intake in both control and intervention groups were sufficiently high to indicate children were already meeting Australian dietary guidelines prior to the intervention (Magarey, Golley, Spurrier, Goodwin, & Ong, 2009).

A second Australian study evaluated a programme aimed at preschool staff, to encourage the promotion of strategies for improving children's healthy eating and physical activity (Hardy, King, Kelly, Farrell, & Howlett, 2010). The ‘Munch and Move’ randomised cluster trial involved 15 intervention and 14 control preschools (n = 430 children, mean age four years) in Sydney. Staff from the intervention preschools received training on healthy eating, physical activity and limiting recreational screen time. Intervention preschools also received resources including a manual and a small grant for training or purchasing physical activity equipment. The impact of the intervention on children’s fruit and vegetable consumption was measured through evaluations of children's lunchbox contents pre and post-intervention. While some improvements in other health behaviours were observed, there were no significant differences in servings of fruit or vegetables in the intervention group compared with the control group following the intervention.

Another very recent intervention, ‘Color Me Healthy’ (CMH) targeted four to five year old children’s fruit and vegetable intake in a preschool setting (Witt & Dunn, 2012). In total 17 preschools were randomised to either the CMH intervention condition (10 preschools, n=165 children) or a no-treatment control (7 preschools, n=98 children). The CMH intervention comprised three 30 minute interactive ‘lessons’ per week, over a six week period, and was delivered by preschool teachers in the classroom setting. The majority of ‘lessons’ focused on learning about fruit and vegetables. Children were also provided with several opportunities to taste these foods. Songs, reproducible parent newsletters and other materials were also included in the intervention. Children’s intake (measured in grams and calculated as a percentage of the total amount offered) of a fruit and vegetable ‘snack’ was assessed one week before the intervention and one week, and three months, post-intervention. Significantly higher fruit and vegetable snack intakes were reported for children in the intervention condition compared to the control condition at both follow-ups. Children who took part in the CMH program increased their consumption of fruit by approximately 31.2% and vegetables by approximately 24.2% between the baseline and one week follow-up assessments and continued to show an increase three months later.

These six multi-component intervention studies highlight the extent of the challenge faced by researchers and health professionals when attempting to increase children’s acceptance of fruits and vegetables. Despite intensive intervention programmes, only two of the studies reported significant increases in children’s intake of both fruit and vegetables (De Bock et al., 2012; Witt & Dunn, 2012). A third study reported a small positive intervention effect on combined fruit and vegetable intake (Wyse et al., 2012), and another reported an effect for fruit only (Vereecken et al., 2009). The final two studies found no intervention effect on either fruit or vegetable intake (Haire-Joshu et al., 2008). Given that effective increases in intake seem harder to achieve for vegetables compared to fruit, combining these foods as a single outcome may be misleading (Vereecken et al., 2009). Interestingly, the only studies to have successfully increased preschooler's fruit or vegetable consumption were those that included regular opportunities to taste these foods (De Bock et al., 2012; Vereecken et al., 2009; Witt & Dunn, 2012). Additionally while simply increasing availability of fruit might be sufficient to increase intake in the under-fives (Vereecken et al., 2009), it appears that in most cases direct repeated exposures, in conjunction with parental, teacher and peer modelling, were necessary to achieve even small increases in children's daily vegetable consumption (approximately 15g) (De Bock et al., 2012).

2.1.2. Infants

A UK home-based intervention carried out by Watt et al (2009) is one of few targeting infants less than twelve months of age. Three hundred and twelve mothers and babies were recruited from baby clinics in disadvantaged areas of London and randomised to receive an intervention consisting of monthly home visits from when the infant was aged three to twelve months (Watt et al., 2009). The intervention took a 'holistic approach' to infant nutrition and mothers were given practical support on multiple infant feeding practices, with a particular emphasis on the importance of fruits and vegetables. Follow-up data were collected immediately post- and six months post-intervention. No effect of the intervention was found for vitamin C intake from fruit (the primary outcome of the trial), calculated from a multiple pass 24 hour food recall. However, at the first follow-up when the infant was twelve months old, intervention mothers were found to be more likely to give their child certain fruits (apples and pears) and vegetables (carrots) but not leafy green vegetables (Watt et al., 2009).

A second recent study focussing on infants under one year, compared two intervention conditions; one maternal-focussed condition and one infant-focussed condition, with a control condition in a cluster randomised trial in three urban paediatric clinics in Ohio, USA (French et al., 2012). In the maternal-focussed condition, mothers received direct guidance regarding their own eating patterns and were informed about the influence of their own behaviours on their children. Mothers in the infant-focussed condition received detailed infant feeding advice focusing on serving size, tips for introducing different foods and parental feeding practices. The control or 'usual care' group received a pre-existing infant feeding information booklet. The intervention was delivered at five clinic visits when the infants were two, four, six, nine and twelve months old. Outcome data on infant fruit and vegetable intake were collect via parent-report questionnaires at the final visit when infants were twelve months. The maternal-focussed intervention group were found to give their infants more daily servings of fruit (1.40 vs. 0.94, $p < 0.05$) and vegetables (1.41 vs. 1.03, $p < 0.05$) compared with control mothers. Infant-focussed mothers also gave more fruit servings (1.26, $p < 0.05$) but no intervention effect on vegetable intake was found for this group. However this study does not give clear information on what constituted a serving or whether potatoes were included as vegetables when measuring children's intake, as is typical in the US.

Only two studies that targeted children under two could be identified, suggesting this is a particularly neglected age group when it comes to dietary interventions despite evidence that there might be critical periods for food acceptance. Although the first study did achieve some success in encouraging intervention mothers to provide more of certain fruits and vegetables, these effects were limited to sweet tasting fruits and vegetables, indicating that mothers may be particularly reluctant to offer their infants cruciferous or leafy green vegetables (Watt et al., 2009). The second infant-focussed study reported greater success but again a larger effect of the interventions was seen for fruit, not vegetable intake and actual vegetable consumption remained well below recommended levels in both intervention and control groups (French et al., 2012). However, this study does suggest providing mothers with information aimed at changing their own eating patterns may impact positively on infant feeding behaviours.

2.2. Interventions based on learning mechanisms in children under five

Slightly more encouraging findings have emerged from recent interventions that have utilised techniques, shown to be effective in laboratory studies, such as; 'mere' exposure, rewards, flavour-nutrient learning, flavour-flavour learning and modelling.

2.2.1. 'Mere' exposure interventions

A number of experimental studies have clearly demonstrated the effectiveness of repeated taste exposure for modifying children's food acceptance (Birch et al., 1998; Birch & Marlin, 1982; Birch et al., 1987; Sullivan & Birch, 1990, 1994). Many of these studies were discussed in the previous chapter, and while most were small and laboratory-based, their findings have informed the design of more naturalistic exposure-based interventions aimed at increasing children's liking and intake of vegetables specifically.

A study by Wardle, Cooke, et al. (2003) evaluated the effectiveness of an intervention utilising exposure theory, on British two to six year olds' intake of and preferences for a previously disliked vegetable. One hundred and fifty six parents and their children were randomised into one of three experimental conditions: repeated exposure over 14 consecutive days, nutrition information, and a no-treatment control. Intake (in grams) of the target vegetable was assessed pre-intervention and approximately two weeks later, prior to and following ad libitum consumption. Children's liking was also assessed using a 3-point 'faces' scale (dislike, neutral, like) and children were asked to rank their preference for the target vegetable in relation to five other vegetables using forced choice elimination ranking. Greater increases in vegetable liking, ranking and consumption from pre- to post-intervention occurred in the Exposure group compared to either of the other two groups. In addition, only the Exposure group showed significant increases across all three outcomes.

2.2.2. Exposure plus reward interventions

Studies with school-aged children have shown that offering a reward for tasting a disliked vegetable does not decrease (Wardle, Herrera, Cooke, & Gibson, 2003) and possibly even works to increase (Hendy, Williams, & Camise, 2005; Horne et al., 2004) children's acceptance of fruits or vegetables. The use of contingent rewards, in conjunction with repeated exposure, has been investigated in several recent studies targeting children under five.

The first intervention study to explore the use of rewards, in relation to the modification of vegetable preference in young children, compared the effects of 'mere' exposure to two additional 'exposure plus reward' conditions and a control group (Cooke, Chambers, Anez, Croker, et al., 2011). This UK-based cluster randomised trial allocated 16 school classes of children aged four to six years to one of four conditions; (1) 12 vegetable exposures over three weeks coupled with a tangible non-food reward (sticker) for tasting the vegetable, (2) exposure coupled with a social reward (praise) for tasting the vegetable (3) exposure alone or (4) a no-treatment control. Liking and intake of the vegetable were assessed using the same methods as the previous 'mere exposure' intervention (described above) (Wardle, Cooke, et al., 2003) at pre-, immediately post-, one month post-, and three months post-intervention. Liking and intake were found to increase more in the three intervention conditions than in the control condition immediately following the intervention, and there were no significant differences between the intervention conditions. These effects were maintained in all three exposure conditions at three-month follow-up for liking but the effects of exposure with no reward on intake became non-significant by three months.

The use of ‘mere’ exposure and exposure plus rewards was investigated further in the home setting. A randomised controlled trial of 173 families with three to four year old children investigated the effect of exposure coupled with a tangible reward (a sticker), exposure coupled with a social reward (praise), or a no-treatment control condition on children’s liking and intake of a previously disliked vegetable (Remington, Anez, Croker, Wardle, & Cooke, 2012). Families were recruited through preschools in London, United Kingdom. Parents in the intervention groups offered their children 12 daily tastes of the vegetable, giving either praise or a sticker as a reward for tasting. Assessments of intake and liking were as per the previous two studies described above (Cooke, Chambers, Anez, Croker, et al., 2011; Wardle, Cooke, et al., 2003) and were conducted by researchers immediately post-intervention and one and three months later. Only children in the exposure coupled with tangible rewards condition increased their intake and liking for the vegetable significantly more than did children in the control group and these differences were maintained at the three-month follow-up.

A third randomised controlled trial similarly evaluated the effectiveness repeated exposure and rewards on young children’s vegetable acceptance, in a home setting (Corsini, Slater, Harrison, Cooke, & Cox, 2013). Parents of 185 four to six year old children were recruited through media advertisements in Adelaide, South Australia. Children were randomised to one of three conditions; exposure only (daily tastes for two weeks), exposure plus reward (daily tastes for two weeks with a sticker reward for tasting) or a no-treatment control group. Fieldworkers visited families at home on four occasions to assess vegetable intake and liking; pre-intervention (baseline), immediately post-intervention and one and three months after baseline, using the same procedures as described previously (Cooke, Chambers, Anez, Croker, et al., 2011; Remington et al., 2012; Wardle, Cooke, et al., 2003). A disliked ‘target’ vegetable was selected at the baseline home visit and parents were given verbal and printed instructions for carrying out the intervention. Both intervention groups displayed greater increases in vegetable liking than the control group following the intervention period and these increases in liking were maintained three months later. Children in the exposure plus reward condition also achieved more daily tastings than those in the exposure only condition. However, there was no effect of the intervention on vegetable intake although all three groups did significantly increase their intake over the intervention period.

The positive findings of these reward-based exposure studies are contrary to self-determination theory (Deci, Koestner, & Ryan, 1999) which would predict that the provision of an external reward could undermine an individual’s intrinsic motivation (in this context liking for a food). However, a review of the impact of rewards on food acceptance suggests that the effect of rewards might partly be dependent on the initial liking of the food (Cooke, Chambers, Anez, & Wardle, 2011). Rewarding consumption of initially well-liked foods (e.g. sweet juices) may result in decreases in preference and intake (Mikula, 1989; Newman & Taylor, 1992), whereas being rewarded for consuming disliked foods, such as vegetables may encourage tasting without any detrimental effects on preference (Remington et al., 2012).

2.2.3. Other theory-based interventions

The mechanism of flavour-nutrient-learning (FNL) has received some attention from experimental studies attempting to modify flavour preferences but very little research has attempted to utilise FNL as a strategy for increasing fruit or vegetable intake in children.

A recent study compared the effectiveness of different exposure-based learning strategies for increasing intakes of a novel vegetable in nine to thirty eight month old children (Caton et al., 2012). Children were recruited from six UK nurseries (n=72) and randomly assigned to one of three conditions; a repeated ‘mere’ exposure (RE) condition, a flavour-flavour learning condition (FFL) or a flavour-nutrient learning (FLN) condition. Each child was offered ten exposures to their condition’s respective version of artichoke puree. The puree used in the FFL condition was sweetened with sucrose but was comparable in energy content to the RE puree. The puree used in the FNL condition had neutral tasting sunflower oil added to increase energy density without effecting flavour. Pre- and post-intervention weighed measures of intake in grams were taken for both artichoke puree and a control vegetable puree (carrot). Significantly higher intakes of artichoke puree at follow-up were observed both compared to pre-intervention intakes and compared to the control vegetable intake at post-intervention. Five exposures were sufficient to increase intake. However no difference in artichoke intake was observed between the three different exposure conditions. These findings replicate those of an earlier study investigating the effects of FNL on increasing vegetable preference in older children (Zeinstra et al., 2009). This study suggests that repeated exposure to a pure vegetable flavour is sufficient in increasing vegetable consumption in preschool children, without the need for additional flavour or nutrient stimuli (Caton et al., 2012).

A similar study in Denmark, involving two to three year old children, also compared the efficacy of mere exposure (RE), flavour–flavour (FFL) and flavour–nutrient learning (FNL) in changing children’s intake of a novel vegetable (Hausner, Olsen, & Moller, 2012). An unmodified artichoke puree was served at pre-testing. Increases in intake were observed in both the FFL and RE conditions but remained unchanged in the FNL condition after 10 exposures. Fewer exposures were needed to observe a change in intake in the RE children (5) compared to the FFL children (10) and RE led to the largest increase in intake of unmodified puree at post-test and over six months. Children in the FFL condition also consumed more of the sweet puree than of unmodified puree, suggesting a learned preference for the sweetened taste over and above the pure vegetable.

The related concept of associative conditioning (AC) was used in two recent studies comparing the effect of repeated ‘mere’ exposure (RE) with exposure coupled with a liked dip (AC) (Anzman-Frasca, Savage, Marini, Fisher, & Birch, 2012). The first study (n=41) was a between-subjects design involving three to six year old children attending a childcare centre who were randomly assigned at the class level to a commonly disliked vegetable, and at an individual level to either the RE or AC condition. The experiment comprised eight exposure sessions twice weekly over a four week period. Children were asked to taste a small portion of the vegetable either alone (RE) or with an accompanying dip (AC). Liking and intake of the pure vegetable (in both conditions) were assessed before and after the eight tasting occasions. In both groups children’s vegetable liking and intake increased from pre- to post-test, but there was no difference between the RE and AC conditions. A second study using a within-subject design in which each child was assigned to repeatedly taste two vegetables, one with dip and one without, reported similar findings and no evidence of an effect of AC was found. Again these results indicate that additional flavour or sensory associations do not increase intake and preference for vegetables over and above the effects of repeated exposure. However, although pairing a vegetable with a dip did not result in children liking that vegetable more when it was subsequently served alone, children did prefer vegetables while the dip was present leading the authors to suggest that the addition of liked dips could be used to encourage initial willingness to taste disliked or unfamiliar vegetables in children (Anzman-Frasca et al., 2012).

Modelling by peers, teachers or parents has also been used as a mechanism to successfully increase children's acceptance of foods in interventions targeting fruit and vegetable preference and consumption (Horne et al., 2004). However the majority of these studies have focussed on school-age children (Horne et al., 2004; Lowe, Horne, Tapper, Bowdery, & Egerton, 2004) and few have had a robust randomised control design (Hendy, 1999; Hendy & Raudenbush, 2000). A recent UK intervention with two to four year old children in a nursery school setting used both modelling and rewards to target children's consumption of fruits and vegetables with positive results, although it is difficult to dissect the relative influences of modelling, exposure and rewards given the multifaceted approach. The study found significant increases in target fruit and vegetable consumption were maintained at six months follow-up once rewards had been withdrawn and increased acceptance was even found to extend to non-targeted foods (Horne et al., 2011).

2.3. Summary

In a recent systematic review of interventions designed to increase the consumption of fruit and/or vegetables among children aged five years and under, the authors commented that the paucity of published randomised trials is surprising given the need to increase fruit and vegetable intake globally (Wolfenden et al., 2012). The findings from existing studies are mixed and multi-component approaches seem to provide little return for the intensity of involvement and economic costs incurred. More promising are the results of recent targeted and theoretically driven interventions utilising specific learning mechanisms. There is much evidence to suggest repeated 'mere' exposure is successful in increasing intake of targeted vegetables and while FFL and FNL do not seem have clear benefits, over and above those of 'mere' exposure (Caton et al., 2012), evidence regarding the additional use of rewards to encourage children's consumption of vegetables appears stronger (Cooke, Chambers, Anez, Croker, et al., 2011; Remington et al., 2012).

Although research utilising repeated exposure techniques, in combination with small rewards, has been effective in increasing preschooler's liking and intake of vegetables, these studies have involved intensive input from researchers. The home is an ideal setting for reaching this important target population but intervention designs involving multiple home visits from a trained professional are impractical and do not allow for widespread dissemination. Nonetheless there is plentiful evidence demonstrating the strong influence of parental behaviour and the home food environment on children's preferences and eating behaviours. Practical, low-cost intervention designs that target young children in the family-setting are needed to increase vegetable and fruit acceptance in this age group.

Intervention success is generally measured in terms of average effects in groups of children, without specifically looking at differences in intervention effects between individual children. Interventions aiming to modify food preferences using repeated exposure have been successful on the group level, but are rarely successful for all individuals. There is little understanding as to why some children do seem to respond to repeated exposure intervention while others do not. Identifying factors that are related to the extent to which an intervention is successful for an individual may improve our understanding of the underlying mechanism of how interventions work. A first step could be to investigate whether intervention responses are determined by environmental or genetic factors.

CHAPTER 3 . RESEARCH AIMS OF THE CURRENT THESIS

3.1. The key questions this thesis aims to address

The first chapter of this thesis reviewed the available literature describing the development of food preferences over the first five years of life. There is evidence for a strong environmental contribution to children's food preferences, but research attempting to identify the specific familial, sociodemographic and child characteristics associated with preferences for healthy or unhealthy foods is conflicting. It is also likely that genes contribute to a child's unique pattern of food likes and dislikes. However, the relative influence of genes and the environment on food preferences, as derived from classical twin studies, also remains unclear due to the small sample sizes and limited power of existing studies.

Interventions directed at modifying food preferences in young children with the aim of improving dietary health were described in Chapter 2. Few studies attempting to modify young children's food acceptance have been successful. Notable exceptions are interventions based on the technique of repeated 'mere' exposure. However, these interventions are often intensive and costly, limiting widespread dissemination. Furthermore even effective interventions do not seem to work for every child and little research has investigated individual differences in children's responses to these interventions.

The overall aim of this thesis is to build on the existing evidence surrounding the aetiology and modification of food preferences in early childhood by addressing a number of the gaps or limitations in the current literature. Specifically, it aims to address the following questions:

1. What patterns of food preferences are observed in infants and young children?
2. What factors are associated with a greater liking for healthy or unhealthy foods in young children?
3. To what extent are food preferences determined by genetic or environmental factors in infancy and early childhood?
4. Can a mere exposure intervention be delivered cost effectively?

The studies undertaken for this thesis attempt to address each of these questions in turn. Study 1 (chapter 5) explores the pattern of preferences for multiple foods in infancy and early childhood. Study 2 (chapter 6) examines the associations between sociodemographic, family dietary and child appetitive characteristics and young children's preferences for both nutrient-rich and energy-dense foods. Studies 3 and 4 (chapters 7 and 8) investigate the relative contributions of genes and environment to children's food preferences and fussy eating behaviours. Study 5 (chapter 9) is a randomised control trial of a new low-cost and easily disseminable intervention to increase preschool children's acceptance of vegetables. Finally, since responses to behavioural interventions vary considerably, study 6 (chapter 10) uses the twin design to explore whether children's responses to the intervention are moderated by genetic or environmental factors.

3.2. My contributions to the research included in this thesis

The data used in this thesis come from a large population-based birth cohort of twins, Gemini – Health and Development in Twins. The measures involved in each of the reported studies were collected between January 2008 and November 2011 and are described in detail in Chapter 4. The 'Tiny Tastes' intervention study was conducted between March 2011 and April 2012 in a sub-sample of the Gemini cohort. The Gemini Questionnaires are discussed in detail in Chapter 4 and presented in Appendix 1.

I began working as a Research Assistant on the Gemini study in January 2009. As such, I had the opportunity to contribute to multiple waves of data collection, starting soon after Gemini was first established. I coordinated the sending of thousands of postal questionnaires and assisted with the creation of a method for establishing regular online contact with participating families. I also contributed to the design and maintenance of the study contacts databases, as well as the day to day management of contact with Gemini families. This included handling inquiries from participants and contributing to participant engagement via the Gemini website (www.geministudy.com) and annual newsletters.

I contributed to data collection and data entry for the 15 month questionnaire (T1), 20 month diet diaries (T2), 24 month questionnaire (T3) and all the anthropometric measurements. Together with the other team members, I was also involved in the collection and management of DNA for zygosity testing, as well as the data collection and entry of the second zygosity questionnaire (T4). Dr Ellen van Jaarsveld, the Gemini study coordinator (and my supervisor) cleaned the data for the T0, T1, T2, T3 and T4 Questionnaires.

For the 3 year questionnaire (T5) I played a key role in the choice or design of all questionnaire measures and took full responsibility for data collection and data cleaning. For the ‘Tiny Tastes’ intervention I applied for and obtained ethical approval. I personally designed and created participant information leaflets, intervention instructions, study plans, consent forms, test instructions, test record sheets and follow-up questionnaires (see Appendix 3). I was also responsible for overseeing the filming and editing of the online videos that accompanied the intervention. The ‘Tiny Tastes’ booklet was designed by Dr Lucy Cooke (my supervisor) in conjunction with a graphic design team. In collaboration with my supervisors (Professor Jane Wardle, Dr Lucy Cooke and Dr Ellen van Jaarsveld) I decided on the ‘Tiny Tastes’ intervention study design. I also coordinated the ‘Tiny Tastes’ intervention in Gemini and organised the posting of all intervention materials, reminders and follow-up questionnaires and cleaned the study data.

Dr Clare Llewellyn tutored me in the principles of quantitative genetic modelling and introduced me to the software used for these analyses. Under her supervision I learned to run univariate models (used in Studies 3 and 6), including writing my own scripts and interpreting output. The complex multivariate models (used in Studies 3 and 4) were more challenging but with assistance I learned to run these models myself and became proficient at interpreting the output. All the analyses in this thesis were performed by me unless otherwise indicated, and I came up with the overall thesis aim.

CHAPTER 4 . GEMINI – HEALTH AND DEVELOPMENT IN TWINS

4.1. Overview of Gemini

Gemini is a prospective cohort study of young twins born in England and Wales between 1st March and 31st December 2007. The Gemini study was established by Professor Jane Wardle within the Department of Epidemiology and Public Health at University College London. It is the first twin cohort set up with the aim of investigating the genetic and environmental influences on growth trajectories in early childhood, primarily focussing on appetite, food and activity preferences and the family environment (van Jaarsveld, Johnson, Llewellyn, & Wardle, 2010). The objectives of the Gemini study are: (a) to further understanding of the genetic and environmental influences on adiposity, (b) to identify modifiable factors contributing to accelerated growth and excessive weight gain in childhood, and (c) to generate a comprehensive resource of data on early childhood exposures (during the first five years of life) that can be utilised to investigate determinants of long-term health. Gemini focusses on the potential behavioural mechanisms behind weight gain (such as appetite and food preferences). Through collecting data on multiple aspects of the family food, activity and media environments along with the child's appetitive traits and feeding behaviours, the Gemini study aims to characterise the extent to which 'obesogenic' behavioural traits are expressed in different rearing environments.

4.2. Methods

4.2.1 Sample, recruitment and attrition

The flow of families participating in the Gemini study between 2007 and 2011 is presented in Figure 4.1. In January 2008 the government agency responsible for birth registration (the Office for National Statistics [ONS]) wrote to all families with twin births in England and Wales between March and December the preceding year (N=6754), to ask for consent to pass their contact details on to the UCL research team. Data was cross-referenced with information from National Health Service Central Registry (NHSCR) to confirm that the mother and both twins were alive. Just over half (51%) of the families approached (*N*=3435) consented in writing to be contacted by the research team. All of these families were subsequently sent the baseline questionnaire (T0), together with a study information leaflet, and a consent form, to be returned with the questionnaire (the questionnaire, introduction letter, information leaflet and consent form can be found in Appendix 1). 2402 families completed and returned the baseline questionnaire; these included 36% of the families initially contacted by ONS or 70% of the families that agreed to being contacted by the research team. The initial 36% response rate to ONS was considered satisfactory given that the families being contacted had infant twins of less than 9 months old and a final response rate of 70% reached expectations, given the length of the baseline questionnaire. The participating families were located across England and Wales at the time of recruitment. Ethical approval for the Gemini study was granted by the Joint UCL/UCLH Committees on the Ethics of Human Research.

The second questionnaire (T1) was sent to all the families that had completed and returned the baseline questionnaire. This questionnaire was sent between June 2008 and March 2009 on a rolling month by month basis in order that each family received it when their twins were approximately 15 months of age. The T1 questionnaire was completed and returned by an acceptable 80% of the baseline cohort (1930 families).

The numbers of Gemini families completing each of the subsequent questionnaire booklets have steadily decreased but remain adequate considering the time commitments involved. The numbers of families completing three day diet diaries (T2) and who provided DNA samples (T4) for their twins were slightly reduced as was expected for these more intensive or intrusive study components. The response rate for the ‘Food likes and dislikes’ questionnaire (T5), sent in November 2010, was 56% of the baseline cohort (1337 families). Attrition rates have remained relatively low with only 58 families (2%) withdrawing from the study between T0 and T5 and only 56 families (2%) officially lost to follow-up over this period.

4.2.2. Data collection and questionnaire measures [9]

All Gemini data has been collected via parent-report and the primary method of data collection has been via paper or digital (online) questionnaires. To date there have been seven rounds of data collection involving the full Gemini cohort. The first baseline questionnaire (T0) was completed when the twins were approximately eight months old. The second questionnaire (T1) was completed when the twins were around 15 months old. When the twins were 20 months old, the third round of data collection (T2) invited families to complete three day dietary records for each of their twins. The fourth

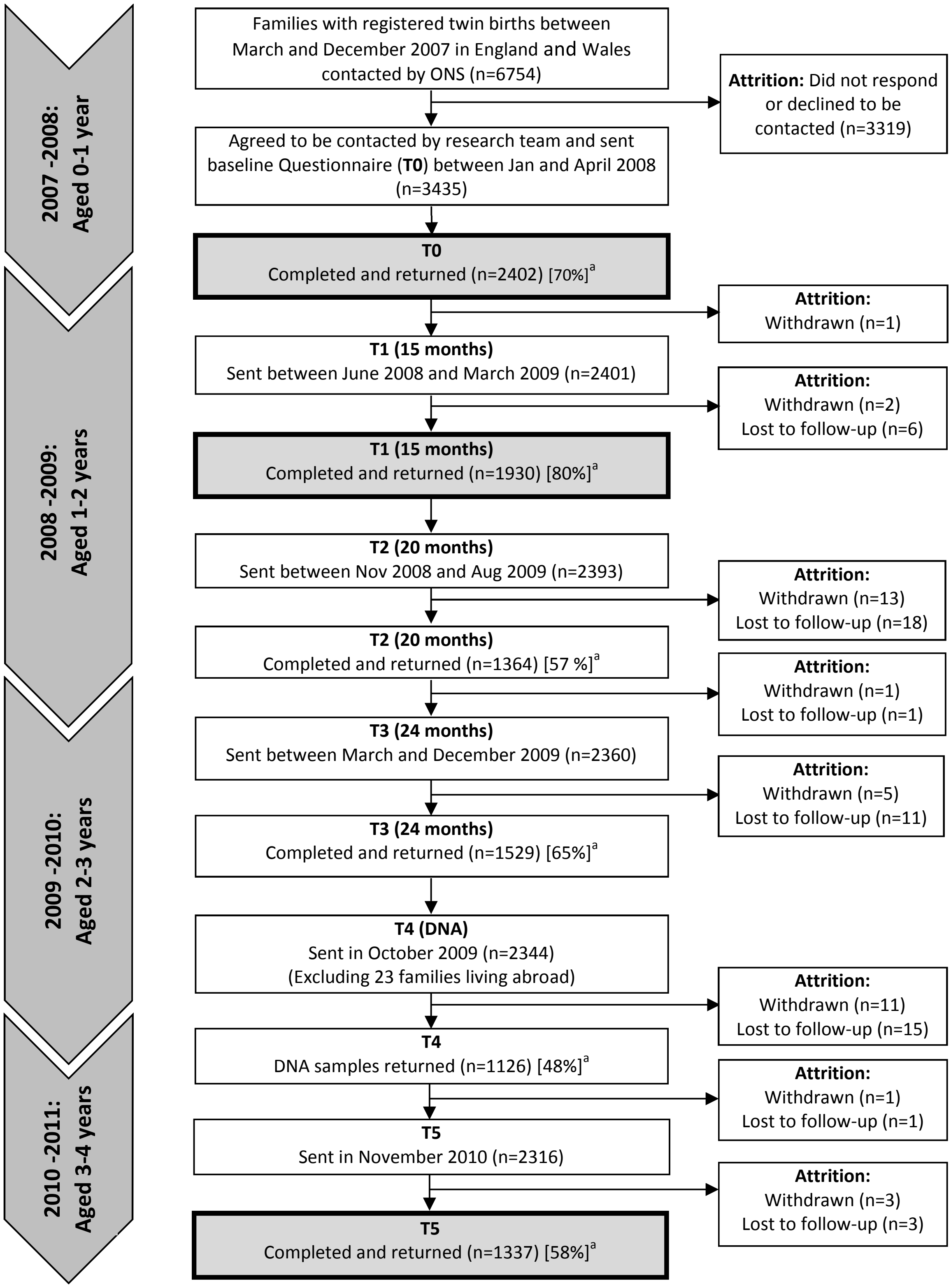
[9] The materials for the Gemini study are shown in Appendix 1.

phase of data collection (T3) was a questionnaire sent when the twins were approximately two years old, focussing on parental health behaviours. In October 2009, Gemini families were sent materials and instructions for collecting DNA samples from their twins which could then be returned through the post (T4). In November 2010 when the twins were approximately three years of age, the families were sent a further questionnaire asking about the twins' food preferences and eating behaviours (T5). The seventh round of data collection, between November 2010 and March 2012, took the form of a telephone interview with a central focus on the home food and activity environment (T6). The most recent data collection round comprised a comprehensive questionnaire (T7) sent when the twins were five years old. All the questionnaires (T0, T1, T3, T5 and T7) have been available both in hard copy and via the internet. Online response rates have increased steadily throughout the five years since the study began, with 9.7% of families completing the baseline questionnaire online compared to online completion rates of 43.7% for T5 and 65.2% for the T7 questionnaires.

All measures that were specifically designed for Gemini were intensively piloted in parents of young children (both singletons and twins). All other measures were based on validated questionnaires. This thesis primarily uses data collected from the T0, T1 and T5 questionnaires. The majority of family demographic data were collected in the baseline questionnaire (T0). The parent completing the questionnaire was asked to state her/his relationship to the twins and to provide information about both her/himself as well as her or his cohabiting partner, if applicable. The questionnaire included items on the mother's pregnancy and birth of the twins, parental anthropometrics, health behaviours, ethnicity and sociodemographics, as well as information on the weight and health of the wider family. There was also a section dedicated to the twins, including; anthropometrics from birth onwards, appetite and feeding behaviour, activity behaviour, parental feeding practices and zygosity information.

Other Gemini data included in this thesis comes from the second questionnaire when the twins were approximately 15 months old (T1) and from the sixth round of data collection, the 'food likes and dislikes' questionnaire, completed when the twins were three years old (T5). The second questionnaire (T1) asked the completing parent to state her/his relationship to the twins and her/his current employment status, as well as that of her/his partner, if applicable. With these exceptions, the questionnaire contained items exclusively relating to the twins, including; anthropometrics, appetite and feeding behaviour, food preferences, activity behaviour (including sedentary activity and sleep) and parental feeding practices.

Figure 4.1: Flow of families through the Gemini study between 2007 and 2011



[a] Response rates are given in square brackets [%]

The boxes representing the key phases of data collection for the current thesis are highlighted

The T5 questionnaire focussed on the twins' food preferences and included a long and varied list of individual foods. In addition, the questionnaire included items on the twins'; anthropometrics, food fussiness, pickiness, neophobia and sensory sensitivity. Copies of the T1 and T5 questionnaires are included in Appendix 1.7 and Appendix 1.8. The measures included in this thesis are described in more detail below.

4.2.2.1. Twin zygosity

4.2.2.1.1. Zygosity questionnaire

All opposite-sex twins were classified as dizygotic (DZ). Parents of same-sex twins completed a 20 item questionnaire (included in T0 and T4) that was developed previously to establish the zygosity of 18-month old twin pairs in the Twins Early Development Study (TEDS) (Price et al., 2000).

The majority of questions focus on markers of physical resemblance including general likeness (e.g. 'Would you say that your twins are: (i) as physically alike as 'two peas in a pod'; (ii) are as physically alike as brothers and sisters are, or; (iii) do not look very much alike at all?'), and specific features such as eye colour, ear lobe shape, hair colour and texture and timing of first tooth growth (e.g. 'Are there differences in the shape of your twins' ear lobes?'); other items refer to blood type and the ease with which parents, friends and other family members can tell the twins apart (e.g. 'When looking at a new photograph of your twins, can you tell them apart without looking at their clothes or using any other clues?'); one question asks about the opinion of healthcare professionals and another asks about the parents' own opinion about their twins' zygosity (e.g. 'Do you think your twins are identical or non-identical?').

Based on the questionnaire responses, zygosity was derived through three possible methods. The simplest method involved twin pairs with discordant blood types, as these could always be identified as DZ. In other cases, specific questionnaire items were considered of higher relevance and therefore held greater weight in assigning zygosity status. This meant that the response to one of these items alone could be sufficient to classify a twin pair, for example – twin pairs described as 'two peas in a pod' were classified as monozygotic (MZ) as this question by itself has been shown to correctly classify a high percentage of MZ twin pairs (Cederlof, Friberg, Jonsson, & Kaij, 1961). Conversely, twins described as 'not looking much alike at all' or as having distinct differences in eye colour, hair colour or hair texture were classified as DZ. However, when a twin pair was described as both being like 'two peas in a pod' and also as having distinct differences, it was not possible to classify their zygosity using this system. In these cases, the classification of twin pairs was based on the scoring system described below.

A scoring system, based upon the responses to the items was used to classify zygosity for twin pairs whose parents had provided ambiguous or contradictory responses on the highly weighted items. A total score was calculated by adding up the scores obtained for each item and dividing the total by the maximum possible score based upon the number of questions answered, to provide a value between 0 and 1. A score of 0 represented maximal similarity, with a score of 1 representing maximal dissimilarity. Therefore, a lower score suggested higher intra-pair similarity and specifically twin pairs scoring $\leq$ 0.64 were classified as MZ. Similarly higher scores indicated lower intra-pair similarity and all twin pairs with scores $\geq$ 0.70 were classified as DZ. Twin pairs with scores > 0.64 and < 0.70 were coded as having ‘unknown’ zygosity in-concordance with the instructions from the original paper outlining the development and validation of the questionnaire measure[10] (Price et al., 2000). Finally, twin pairs who had missing data for 50% of the items or more were classified as having ‘unknown’ zygosity.

The questionnaire performed well when validated against DNA in the TEDS sample, with an accuracy level of 95%. It has also demonstrated reliability over time with 96% of twins being assigned the same zygosity at 18-months and 3 years of age (Price et al., 2000).

4.2.2.1.2. DNA validation of the zygosity questionnaire

During the fifth wave of data collection (T4), when the twins were approximately 3 years old, all of the Gemini families were invited to collect and return DNA samples for each of their twin children and to complete the zygosity questionnaire for a second time (this was the same zygosity questionnaire completed at T0) . DNA was primarily collected in order to measure molecular genetic variants of interest but the genetic information was also used to check the validity of the zygosity questionnaire. A random sample of 10% of the twin pairs for whom a DNA samples were provided (*n* = 81 pairs; 43 MZ pairs, 38 DZ pairs) were zygosity-tested using DNA analysis. This process was carried out at the Institute of Psychiatry at Kings College London. In every one of the 81 cases tested (100%) the zygosity questionnaires and DNA-based test provided the

[10] The distribution of scores from the questionnaire showed a binomial distribution – and twin pairs who sat in the overlap between the two bimodal curves were considered of ‘unknown’ zygosity. This included all twin pairs with scores between 0.64 and 0.70.

same classification of twin pairs, suggesting an extremely high accuracy level of the zygosity questionnaire.

Zygosity results from the two administrations (T0 and T4) were also compared in 934 pairs to assess the test-retest correlation and percentage agreement of the questionnaire. For 66 pairs, zygosity could not be decided based on T0 or T4 questionnaires; leaving 868 pairs with results on both occasions. Of these, 827 (95.3%) were assigned the same zygosity on both occasions. The Spearman correlation coefficient was 0.80 ($p < 0.001$) and the Kappa statistic (a measure of agreement) was also 0.80 ($p < 0.001$), indicating good test-retest reliability. DNA of an additional 86 pairs were selected and tested because the first zygosity questionnaire results (T0) did not match the later questionnaire result (T4) or the result on either questionnaire was uncertain. Inconsistent results between T0 and T4 were observed for 41 pairs out of the 868 (4.7%) whose results were classified on both occasions. DNA was available for 34 of these and confirmed that the second zygosity questionnaire (T4) was correct in 79.4% of pairs, while the first zygosity questionnaire was correct in 20.6% of cases. In 30 pairs, the results from the first questionnaire were uncertain but zygosity could be allocated using the second questionnaire (T4) and DNA confirmed the results of the second questionnaire were accurate in all 30 pairs. For 29 pairs the second zygosity questionnaire (T4) provided uncertain results while the first (T0) allocated zygosity and these allocations were confirmed for 78% of these pairs with DNA.

The final zygosity allocations for the 1586 same-sex twin pairs, used in this thesis, were based on all available evidence including, the T0 zygosity questionnaire, the T4 zygosity questionnaire and DNA testing. In total, 214 pairs were allocated zygosity according to DNA evidence, 718 pairs were allocated zygosity based on T0 and T4 zygosity questionnaires (with matching zygosity at both assessments) , 609 pairs were allocated based exclusively on the T0 questionnaire (as T4 data were missing), 7 pairs were allocated zygosity exclusively based on the T4 questionnaire (T0 zygosity was classified as ‘unknown’) and for 38 pairs zygosity could not be allocated either due to conflicting outcomes from the two questionnaires (8 pairs) or because both questionnaires failed to classify zygosity (Price et al., 2000).

4.2.2.1.3. Health professional and parental misclassification of zygosity [11]

The 100% agreement between the questionnaire and DNA allocation of zygosity is especially reassuring given that parental and health professional opinion of their twins' zygosity did not always agree with the questionnaire. Parents were asked if they thought their twins were identical. This item was used to sub-categorise the zygosity further into those who were similarly classified by both the zygosity questionnaire and the parents (e.g. MZ/MZ) and those whose questionnaire classification and parental classification differed (e.g. MZ/DZ), giving rise to four possible groups: (1) pairs classified as MZ by both the questionnaire and the parents [MZQ-MZP] (*n*=513 pairs); (2) pairs classified as MZ by the questionnaire and as DZ by the parents [MZQ-DZP] (*n*=216 pairs); (3) pairs classified as DZ by both the questionnaire and the parents [DZQ-DZP] (*n*=1589 pairs); (4) pairs classified as DZ by the questionnaire and as MZ by the parents [DZQ-MZP] (*n*=16 pairs). In total, questionnaire classification and parental classification were discordant for 10% (232) of twin pairs and in the majority of these cases parents believed their twins to be DZ while the questionnaire classification was MZ.

Parents of same-sex twins were also asked whether they had been given zygosity information by a health professional at any time. The majority of parents (82%) said that they had been given zygosity information by health professionals based on the separateness of placentation as seen on prenatal scans. For the remaining twin pairs either no opinion had been given or the opinion of the health professional was based on other information (e.g. DNA, septal thickness), conflicting information had been given, or the source if the information was not specified by the parents. Using the zygosity questionnaire classification of twin type and available DNA data, it was found that 191 parents (14.7%) were misinformed by health professionals about zygosity based on prenatal scan observations. As many as 27.5% of parents of MZ twins mistakenly believed that their twins were DZ (179 out of 651 pairs), compared with just 2% of parents of DZ twins who mistakenly believed their twins were MZ (12 out of 621 pairs).

In total, 38% of parents said that they were told after an antenatal scan that their twins shared a placenta and were therefore MZ, whereas 62% of parents were told that their

[11] The information provided here is described in more detail in the following paper: van Jaarsveld C, Llewellyn C, Fildes A, Fisher A, Wardle J. Are my twins identical: parents may be misinformed by prenatal scan observations. BJOG 2012;119:517–518.

twins were DZ because they were dichorionic diamniotic (DCDA). In reality, two separate placentas and amniotic sacs do not denote dizygosity and 25–30% of MZ twins are in fact DCDA because early splitting of an MZ zygote (within 2 days of fertilisation) results in separate placentas (Hall, 2003). This suggests a lack of knowledge regarding chorionicity and zygosity, among some UK health professionals, because the proportion of parents who were apparently misinformed closely matched the prevalence of DCDA in MZ twins in the Gemini study.

4.2.2.2. Twin anthropometrics

Weight data at birth and in the first months after birth was collected in the baseline questionnaire. Parents reported their children's weights from birth onwards using measurements completed by health professionals and recorded in the child's personal health record ('red book'). Parents were asked to photocopy the relevant pages of their child's red book or copy all available measurements for each twin directly into the questionnaire. When health professional weight measurements were unavailable, parents were asked to include weight measurements they had recorded themselves (3.6% of data collected in the T0 questionnaire).

In 2009, when the twins were approximately two years old, all families were sent a standardised measurement chart for recording their children's height and a set of digital weighing scales. Parents were reminded at three monthly intervals to weigh and measure their twins and to record this information, along with the dates on which all measurements were taken. Parents were prompted to send up-to-date anthropometrics at subsequent rounds of data collection (T3, T5, T6 and T7) and through an online form accessed via the Gemini study website. Response options (at all time points) allowed for the provision of anthropometric data in imperial or metric units and all imperial data were later converted to metric. In cases where information was provided in both forms of measurement, the metric units were used. Birth weights below 0.5 kilograms (kg) and above 5.0 kg were considered misreports and were therefore coded as missing.

Between birth and when the twins were on average 6.5 months of age (SD= 2.5, range=1.5–22), parents reported a mean of 9.6 weight measurements per child (SD=5.4, range=1–45) (Wijlaars, Johnson, van Jaarsveld, & Wardle, 2011). Data were checked and implausible values were deleted. At '3 months', '15 months' and '3.5 years' weight variables were derived for each twin. At each age, in order to maximise the size of the sample with available data, a 'window of measurement' was created. For '3 month' weight the weight measurement occasion closest to 3 months that occurred between 2 and 4 months was selected to represent ‘3-month’ weight. Age at the ‘3-month’ measurement occasion was also noted. For ‘15 month’ weight the measurement taken closest to 15 months that occurred within a six month window either side (i.e. between 9 months and 21 months) was selected. For ‘3.5 year’ weight the measurement taken closest to when the child was 3.5 years that, again, occurred within a six month window either side of this age (i.e. between 3 years and 4 years) was selected. Ages at the ‘15-month’ and ‘3.5 year’ measurements were also noted.

Weight standard deviation scores (SDS) at birth and all subsequent ages were calculated by adjusting for sex, age and gestational age, based on British 1990 growth reference data using the LMS growth macro for excel (Cole, 2009; Freeman et al., 1995).

4.2.2.3. Sociodemographic information

4.2.2.3.1. Age

Chronological age (in months and/or years) at the time of each data collection phase was calculated using the twins’ date of birth and the date upon which the relevant questionnaire was completed. Gestational age (in weeks) was also recorded for every twin pair. Parents were asked to report the number of weeks the mother had been pregnant at the time of delivery and this was used as an estimate of gestational age. Parents’ age at the time of their twins’ birth was calculated (in years) using the twin’s date of birth and each parent’s date of birth.

4.2.2.3.2. Marital status

The parent completing the baseline questionnaire provided information about their marital status using one of the following categories: ‘married or cohabiting’, ‘divorced’, ‘widowed’, ‘separated’ or ‘single’. The categories were later collapsed into ‘married or cohabiting’, ‘divorced or separated’ or ‘single’, based upon numbers and conceptual distinction.

4.2.2.3.3. Socioeconomic status

Information on multiple indicators of family social class was collected in the baseline questionnaire, including parental education and parental occupation. Parents were asked to report their highest educational qualification from seven options: ‘No qualifications’, ‘CSE, GCSE or ‘O’ level’, ‘Vocational qualification (GNVQ, BTEC)’, ‘’A’ or ‘AS’ level’, ‘Higher National Certificate (HNC) or Diploma (HND)’, ‘Undergraduate degree', 'Postgraduate qualification (Masters, PhD)'. Education level was subsequently collapsed into three categories: 'low' included 'No qualifications' and 'CSE, GCSE or 'O' level'; 'middle' included 'Vocational qualification (GNVQ, BTEC)' and ''A' or 'AS' level'; 'high' included 'Higher National Certificate (HNC) or Diploma (HND)', 'Undergraduate degree' and 'Postgraduate qualification (Masters, PhD)'.

Parents also described their occupation and that of their partner and this was used to calculate the National Statistics Socioeconomic Class (NS-SEC) index. NS-SEC was classified using the simplified method described by the ONS (Office for National Statistics, 2005), using the Computer Assisted Structured Coding Tool (R. Jones & Elias, 2005). This tool assigns job descriptions to a corresponding four digit Standard Occupational Classification 2000 code (Office for National Statistics, 2000a, 2000b). These codes are then linked to a reversed eight category NS-SEC classification; with higher scores represent higher socioeconomic class. The person in the household with the highest score was defined as the household reference and their score represented household NS-SEC. The reference person was the partner for 41% of families, the mother for 29% of families and was equal in 18% of families. In the other 12% of families, data were missing or the mother was single and therefore, the person with NS-SEC data was automatically assigned as household reference person. NS-SEC scores were grouped into three categories in order to have adequate group sizes for analyses. These categories are: higher (higher and lower managerial and professional occupations), intermediate (intermediate occupations, small employers and own account workers – self-employed with no employees) and lower occupational classifications (lower supervisory and technical occupations, (semi-) routine occupations, never worked and long-term unemployed) (Office for National Statistics, 2005).

The three category NS-SEC measure is the primary method for allocating family SES in this thesis. The NS-SEC has been developed on a clear theoretical basis. has been demonstrated to have clear construct validity in identifying social class differences in validated health outcome measures and is a useful tool for explanations of inequality in health (Chandola & Jenkinson, 2000).

4.2.2.3.4. Ethnicity

In the baseline questionnaire, respondents selected their own ethnicity, and that of their partner, from 16 possible categories. Categories were taken from ONS's National Statistics interim standard classifications for presenting ethnic and national groups data (categories include 'White British', 'White Irish', 'Other White background', 'Caribbean', 'African', 'Other Black background', 'Indian', 'Pakistani', 'Bangladeshi', 'Other Asian background', 'White and Black Caribbean', 'White and Black African', 'White and Asian', 'Other Mixed background', 'Chinese', 'Any other'. In all cases of 'other…' parents were asked to provide additional information). Categories were then collapsed into 'White-British' and 'Non White-British' (and 'unknown' in the cases of missing data) because numbers across the Non White-British categories were too small to enable subgroup analyses among specific ethnic groups.

4.2.2.3.5. Parental health behaviours

Parental health behaviours were also assessed as part of the baseline questionnaire. Parents reported on the frequency of fruit and vegetable servings they had eaten in the last week, with eight response options ranging from 'less than 1 per week' to '4 or more per day', based upon those used in the European Prospective Investigation of Cancer study (Sargeant et al., 2001). A measure of total consumption of fruits and vegetables was estimated using the following method; first, separate scores for fruit and vegetable intake were calculated by recoding the 8 response categories (using the scoring system: 1=0.1, 2=0.2, 3=0.4, 4=0.8, 5=1, 6=2, 7=3, 8=4). These scores represented the number of portions of either fruit or vegetables consumed in one day. Adding the two scores together then provided an estimation of the total number of combined portions of fruit and vegetables consumed during one day. Scores were calculated for both parents.

4.2.2.4. Infant feeding method

Mothers were asked to report on the feeding methods they used for each twin during their first 3 months of life. The proportion of breastfeeding and formula feeding, was assessed using the question: 'Which feeding methods did you use in the first three months', with response options: 'entirely breastfeeding'; 'mostly breastfeeding with some bottle-feeding'; 'equally breastfeeding and bottle-feeding'; 'mostly bottle-feeding and some breastfeeding'; 'almost entirely bottle-feeding (only tried breastfeeding a few times)'; 'entirely bottle-feeding (never tried breastfeeding)'; and 'other'. It was explained in the questionnaire that 'breastfeeding' referred to feeding an infant with breast milk, either directly from the breast or expressed milk from a bottle, while bottle-feeding referred to formula milk given from a bottle.

4.2.2.5. Timing of solid food introduction

Questions assessing the children's age when they were first introduced to solid foods were initially asked at T0 and then repeated at T1. The solid food questions were asked on a second occasion (T1) because 55% of infants had not yet tried multiple foods (primarily non-core foods) at the time of the baseline questionnaire (T0). In each questionnaire, parents were asked, in months, 'at what age did your twins start taking solid foods every day?' with separate responses for each twin. In addition parents were asked the questions: 'Has either of your twins tried these foods yet? If so, how old were they when they first tried it?' for a list of 18 foods and drinks, such as 'Baby rice, cereal, rusks or bread'. Again, separate responses were provided in months for each twin.

To create the 'age at solid food introduction' variable, where possible responses were taken from the single item question at baseline (T0). If responses were not available at baseline, data were taken from the single item in the 15-month questionnaire (T1). This ensured that responses were given closer to the time of food introduction. There was a small proportion of children (n=266), for whom data were missing for the single solid foods question in both the T0 and T1 questionnaires. For some of these children it was possible to derive the age at solid food introduction using the responses provided from the individual food questions. Therefore, in order to maximise data, children with missing data on the individual solid food questions had their age at solid food introduction imputed based on the earliest response provided for the individual food questions (n=215), leaving only 51 twins with missing data on this variable.

4.2.3. Heritability analyses using twins

This thesis employs quantitative genetic modelling techniques to estimate heritability for a number of phenotypes using the Gemini twin sample. Quantitative Genetics Theory (QGT) is based on the assumption that underlying genetic and environmental effects contribute to the total variance in any given continuously measured trait or phenotype. The genetic contribution is the combination of all the genetic effects, including interactions between the genes. The environmental contribution includes any effects that are not directly caused by the functional effects of genes. The environmental effect may be sub-divided into: (1) the shared environment, which includes all aspects of the environment that any two relatives share in common and that contributes to their similarity for a particular trait (e.g. attending the same school or siblings being treated the same by their parents), and (2) the non-shared or unique environment, which includes all aspects of the environment that are unique to an individual (that he or she does not share in common with other relatives) and that do not contribute to two relatives being more alike (e.g. illness, traumatic events, unique relationships) (Plomin, DeFries, McClearn, & McGuffin, 2008).

Family studies and twin designs have long been used by behavioural researchers to establish the relative influences of genes and environment on traits. The extent to which relatives correlate on a particular trait is compared to the values that would be expected from their genetic relatedness. If correlations are higher for more closely genetically related individuals then some genetic influence is assumed; if they are not, then environmental influences may be assumed. Twins provide an extremely effective and convenient design for studying the genetic and environmental influences on any given trait. Unlike singleton siblings or other family members, twins reared together are closely matched on age, familial and social influences, making it easier to interpret the shared environment effects. Additionally, the key difference between MZ and DZ twins is the extent to which they are genetically similar; MZ twins share 100% of their DNA, whereas DZs only share on average 50%. Therefore, differences between MZ pair correlations and DZ pair correlations are assumed to result exclusively from differences in the quantity of shared genetic information. This makes it relatively straightforward to estimate the contribution of genes and the environment to the variance of any given trait.

Heritability estimates, which are essentially an index of genetic effect size for a trait, are calculated with twin pairs by comparing associations on the trait of interest between MZ twins, with those between DZ twins. Twin resemblance not attributable to genes is considered to result from shared environmental influences and any remaining variance is thought to reflect ‘unique’ or ‘non-shared’ environmental contributions and measurement error (Plomin et al., 2008).

Rough estimates of heritability or additive genetic effects (a^2) can be calculated by doubling the difference between MZ and DZ correlations on a trait of interest. The shared environment component (c^2) can then be calculated by subtracting the estimate of the additive genetic effect from the MZ correlation, as this reflects how much more alike a shared family environment has made the twins than is predicted by their genetic similarity. The remaining variance (the extent to which MZ twins do not correlate), provides an estimate of the non-shared environment component plus error of measurement (e^2).

The exact equations used to estimate genetic (a^2), shared environmental (c^2) and non-shared environmental effects (e^2) from MZ and DZ correlations are:

(a^2): 2(rMZ – rDZ)

(c^2): rMZ – (rMZ – rDZ)

(e^2): 1 – (rMZ)

More reliable estimates of genetic and environmental effect sizes can be calculated with model-fitting techniques using Mx structural equation modelling software (M. C. Neale, Boker, Xie, & Maes, 2003). These techniques were used to apportion phenotypic variance to genetic and environmental factors in the present thesis and will be described in more detail in subsequent relevant chapters.

4.3. Representativeness of the Gemini sample

4.3.1. Assessing representativeness of samples

The representativeness of the Gemini cohort at baseline was assessed by comparing the characteristics of the Gemini twins and their families with national statistics published by ONS[12] and with nationally representative data from other relevant sources. Analyses were conducted to compare sample characteristics at the three data collection phases used in this thesis. For continuous measures Independent Groups t-tests were used and for categorical measures chi-square tests were used to assess differences between the full Gemini cohort (T0) and each of the subsequent sub-samples (T1, T5). For the majority of analyses in this thesis an alpha level of 0.01 was selected for significance in order to reduce the risk of a Type 1 error resulting from the large sample and multiple tests.

4.3.2. Representativeness of the Gemini sample: Findings

4.3.2.1. The distribution of Gemini families

The representativeness of the Gemini cohort was first assessed by examining the distribution of Gemini families across England and Wales at the time of recruitment. Figure 4.2 shows the distribution of the Gemini families which broadly mirrors the population density despite some small differences in the response rate. Response

[12] These analyses were performed by Ellen van Jaarsveld.

rates ranged from 19% to 45% by region of residence (χ^2=241.261 (9*df*), p<0.001). Response rates were higher in the Midlands, the East of England, the South East of England and the South West of England, and lowest in the Greater London area.

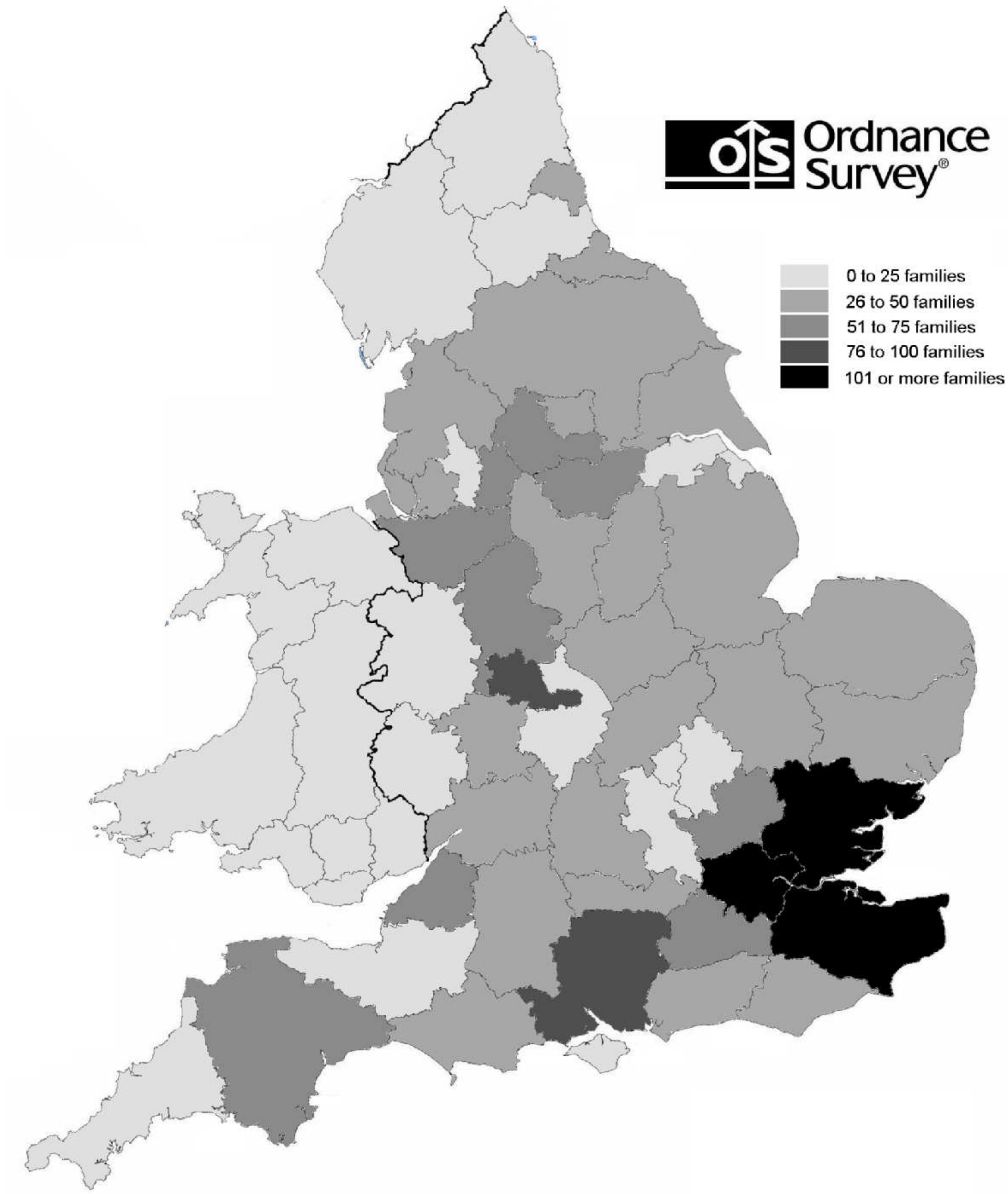
4.3.2.2. Representativeness of the Gemini cohort at key data collection phases

The representativeness of the full Gemini cohort (T0) and the 15 month (T1) and three year (T5) sub-samples in comparison with national statistics are shown in Table 4.1 and Table 4.2. These comparisons do not highlight major concerns about the ability of the full Gemini cohort, or the T1 and T5 follow-up samples, to represent the target population, although slight differences are evident.

In summary; the T0, T1 and T5 samples include twins that are comparable in sex (Office for National Statistics, 2001, 2006a), zygosity, gestational age (Office for National Statistics, 2006a), and birth weight (Office for National Statistics, 2006a) to national averages of twins. In addition, similar rates of exclusive breast- and bottle-feeding were observed in the full cohort sample (T0) as in the population at large (Infant Feeding Survey, 2007) although rates of exclusive breastfeeding increased slightly and rates of exclusive bottle-feeding decreased in the T1 and T5 follow-up samples (Table 4.1). The age at introduction of solid foods in the full cohort was also similar to national averages (T0) (Infant Feeding Survey, 2007) and only increased very slightly in the later samples (T1 and T5).

Table 4.2 shows comparisons between the sociodemographic profiles of the Gemini parents and national statistics at the three relevant data collection phases (T0, T1 and T5). These comparisons indicated that in the full T0 cohort, Gemini mothers were somewhat older at the twins' birth (Office for National Statistics, 2006b), and both parents appeared healthier than the national population with slightly higher rates of at least 5 portions of fruit or vegetables consumed per day (Health Survey for England, 2008). In addition, Gemini has an over-representation of White-British married couples (Office for National Statistics, 2006b, 2007), as in many cohort studies. However, this may in part be due to the target sample for Gemini being young parents, whereas national statistics reference all adults aged 16 and over. Gemini parents scored higher on indicators of socioeconomic status than the national average; educational attainment levels were higher than average for both parents (Department for Innovation Universities and Skills, 2008); a greater proportion of the families were categorised to be of 'higher' socioeconomic status according to NS-SEC, and fewer were categorised as 'lower' compared to the national population (Office for National Statistics, 2003).

Figure 4.2: Map of England and Wales showing the distribution of families participating in Gemini



4.3.2.3. Comparisons of sample characteristics at the key data collection phases

The sample characteristics were compared across the three data collection phases (T0, T1 and T5) to assess the representativeness of the reduced sub-samples, from the later collection phases, compared to the full cohort. Some differences were observed: the T5 sub-sample was heavier at 15 months than the T1 sub-sample (10.26kg versus 10.08kg; t (6546) =5.00, p<0.001). The T1 sub-sample were introduced to solid foods slightly later than the full cohort (4.9 months versus 4.8 months; t (8664) =4.60, p<0.001), but there was no significant difference between the T5 and T1 sub-samples for this variable. A higher proportion of children in the T5 sample were entirely, mostly or equally bottle and breastfed, and fewer were mostly or entirely bottle-fed compared to the full cohort (χ^2=28.72 (5*df*), p<0.001). The T1 sample did not differ from either the full cohort or the T5 sample in terms of milk feeding method.

In the T5 sample mothers were on average more highly educated than the full sample with a higher proportion educated to undergraduate or postgraduate degree level (59% versus 52.1%; χ^2=28.72 (4*df*), p<0.001). Maternal education level in the T1 sample was not significantly different from either the full cohort or from the T5 sample. A similar pattern was observed for paternal education with a higher proportion of fathers educated to degree level in the T5 sample compared to the full cohort (49.6% versus 42.9%; χ^2=15.75 (4*df*), p=0.003), but no difference in paternal education between the T1 sample and either the full cohort or the T5 sample. Likewise the proportion of families in each of the NS-SEC categories was different at T5 compared to the full cohort, with more families in the ‘higher’ SES category at T5 (70.1% versus 63.1%; χ^2=20.76 (2*df*), p<0.001), but there was no significant differences between the T5 and T1 samples or the T1 and the full samples for this variable. Mothers in the T5 sub-sample had lower mean BMI than the full cohort (24.8 versus 25.1; t (7488) = 2.64, p=0.008) but there was no difference in Mothers’ mean BMI between the T1 sub-sample and either the full cohort or the T5 sample.

Overall the majority of the slight differences observed between the full Gemini sample (T0) and national statistics increased in the T1 and/or T5 samples. Increased SES, higher maternal and paternal education, more breastfeeding, later solid food introduction and lower maternal BMI were observed in the T5 sample (and to some extent the T1 sample) comparative to the full cohort at T0.

Table 4.1: Characteristics of twins participating in Gemini at T0, T1 and T5 compared to national statistics for twins

Characteristic	Total Gemini sample (N=4804 twins)	T1 Gemini sample (N=3862 twins)	T5 Gemini sample (N=2686 twins)	National statistics
	N (%[a]) or Mean (sd)	N (%[a]) or Mean (sd)	N (%[a]) or Mean (sd)	% or mean
Weight at birth (kg)	2.46 (0.54)	2.47 (0.54)	2.46 (0.54)	2.50[b]
Weight at 15 months (kg)	-	10.08 (1.46)	10.26 (1.39)	9.95[c]
Weight at 3 years (kg)	-	-	15.47 (1.93)	15.15[c]
Gestational age at birth (weeks)	36.2 (2.49)	36.2 (2.47)	36.2 (2.51)	37[b]
Twin age (months)	8.2 (2.16)	15.8 (1.14)	41.5 (3.29)	
Zygosity of twin pairs				-[d]
DZ –opposite-sex	816 (34.0) *(35.0)*	644 (33.4) *(34.4)*	422 (31.4) *(31.7)*	
DZ – females	389 (16.2) *(16.7)*	315 (16.3) *(16.8)*	228 (17.0) *(17.1)*	
DZ – males	400 (16.6) *(17.1)*	316 (16.4) *(16.9)*	222 (16.5) *(16.7)*	
MZ – females	384 (16.0) *(16.5)*	313 (16.2) *(16.7)*	233 (17.3) *(17.5)*	
MZ – males	345 (14.4) *(14.8)*	283 (14.7) *(15.1)*	225 (16.8) *(16.9)*	
Not known	68 (2.8)	60 (3.1)	13 (1.0)	
Sex of twin pairs				
Males	785 (32.7)	635 (32.9)	455 (33.9)	32.1%[b]
Female	801 (33.3)	652 (33.8)	466 (34.7)	32.8%
Male-female	816 (34.0)	644 (33.3)	422 (31.4)	35.1%
Feeding method of infants				
Entirely breastfed	676 (14.1) *(14.2)*	603 (15.6) *(15.7)*	426 (15.9) *(16.6)*	14%[e]
Mostly breastfed	895 (18.6) *(18.8)*	744 (19.3) *(19.3)*	564 (21.0) *(21.9)*	-
Equally breast- and bottle-fed	446 (9.3) *(9.3)*	358 (9.3) *(9.3)*	271 (10.1) *(10.5)*	-
Mostly bottle-fed	783 (16.3) *(16.4)*	662 (17.1) *(17.2)*	459 (17.1) *(17.8)*	-
Almost entirely bottle-fed	686 (14.3) *(14.4)*	542 (14.0) *(14.1)*	368 (13.7) *(14.3)*	-
Entirely bottle-fed	1090 (22.7) *(22.8)*	773 (20.0) *(20.1)*	484 (18.0) *(18.8)*	23%
Not known	225 (4.7)	180 (4.7)	114 (4.2)	
Age at solid food introduction (months)	4.8 (1.02)	4.9 (0.99)	4.9 (1.06)	4.8[e]

a Italicized percentages are the valid percentages which may be compared to national statistics; non-italicized percentages include missing data. Percentages may not add up to 100 due to rounding.

b Office for National Statistics (2006). Birth Statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales. Newport. (Numbers are for twin births in 2006).

c UK–World Health Organization (WHO) 0–4 years growth charts. Introduced in England from May 2009, the charts, developed for the Department of Health by the Royal College of Paediatrics and Child Health, are based on growth data from breastfed infants and replace earlier charts based on the growth of predominantly formula-fed infants. They were constructed using the WHO standards for infants aged 2 weeks to 4 years, utilising data from healthy children worldwide (C. M. Wright et al., 2010). The weight measurements cited here for 15 months and 3.5 years are derived from the average of the 15 month 50th percentile weight for boys (10.3kg) and girls (9.6kg) and the average of the 3 years 6 months 50th percentile weight for boys (15.3kg) and girls (15kg) (World Health Organization, 2006).

[d] ONS has not published national statistics for these variables.

[e] Infant Feeding Survey 2005 (2007).Incidence, prevalence and duration of breastfeeding. The Information Centre for Health and Social Care. This survey reported that in 2005, 77% of mothers in England and Wales breastfed initially (even if this was on one occasion only), so 23% of infants were never breastfed (corresponding to our 'entirely bottle-fed'), during the first 10 weeks of life. They also reported that 14% of infants were exclusively breastfed for the first three months of life. The mean age for the introduction of solid foods in England and Wales was 19 weeks (4.8 months).

Table 4.2: Characteristics of parents participating in Gemini at T0, T1 and T5 compared to national statistics

	Total Gemini sample (n=2402 families; n=4804 twins)	**T1 Gemini sample (n=1931 families; n=3862 twins)**	**T5 Gemini sample (n=1343 families; n=2686 twins)**	**National statistics**
	N (%[d]) or Mean (sd)	N (%[d]) or Mean (sd)	N (%[d]) or Mean (sd)	% or Mean
Maternal Ethnicity				
White-British	2089 (87.0) (*87.0*)	1702 (88.1)	1197 (89.1)	78.1%[a]
Non White-British	311 (12.9) (*13.0*)	229 (11.9)	146 (10.9)	21.9%
Not known	2 (0.1)	-	-	
Paternal Ethnicity				
White-British	1988 (87.8) (*87.8*)	1633 (84.6) *(88.9)*	1157 (86.2) *(89.9)*	72.6%[a]
Non White-British	275 (11.4) (*12.2*)	203 (10.5) *(11.1)*	130 (9.7) *(10.1)*	72.6%[a]
Not known	139 (5.8)	95 (4.9)	56 (4.2)	
Marital status				
Married or cohabiting	2276 (94.8) *(94.8)*	1848 (95.7) *(95.8)*	1295 (96.4) (*96.5*)	60.0%[c]
Divorced / separated	31 (1.3) *(1.3)*	20 (1.0) *(1.0)*	11 (0.8) *(0.8)*	10.0%
Single	93 (3.9) *(3.9)*	61 (3.2) *(3.2)*	36 (2.7) *(2.7)*	20.0%
Not known	2 (0.1)	2 (0.1)	1 (0.1)	
Maternal Education				
No qualifications	129 (5.4)	85 (4.4)	44 (3.3)	11.9%[f]
CSE, GCSE, O-level or Vocational	763 (31.8)	568 (29.4)	364 (27.1)	40.0%
A or AS-level	258 (10.7)	208 (10.8)	143 (10.6)	16.9%
HNC/HND, or Undergrad Degree	865 (36.0)	739 (38.3)	537 (40.0)	24.3%
Postgraduate Degree	387 (16.1)	331 (17.1)	255 (19.0)	6.9%
Paternal Education				
No qualifications	238 (9.9) *(10.5)*	171 (8.9) *(9.3)*	106 (7.9) *(8.2)*	11.1%[f]
CSE, GCSE, O-level or Vocational	842 (35.0) *(37.0)*	646 (33.5) *(34.9)*	423 (31.5) *(32.7)*	36.3%
A or AS-level	166 (6.9) *(7.3)*	141 (7.3) *(7.6)*	100 (7.4) *(7.7)*	22.3%
HNC/HND, or Undergrad Degree	723 (30.1) *(31.8)*	623 (3.23) *(33.7)*	462 (34.4) *(35.6)*	23.0%
Postgraduate Degree	307 (12.8) *(13.5)*	267 (13.8) *(14.4)*	204 (15.2) *(15.8)*	7.3%
Unknown	126 (5.2)	83 (4.3)	48 (3.6)	

Table 4.2. Continued.

	Total Gemini sample (n=2402 families; n=4804 twins)	T1 Gemini sample (n=1931 families; n=3862 twins)	T5 Gemini sample (n=1343 families; n=2686 twins)	National statistics
	N (%[d]) or Mean (sd)	N (%[d]) or Mean (sd)	N (%[d]) or Mean (sd)	% or Mean
Household NS-SEC				
Lower	472 (19.7) (*19.7*)	323 (16.7) *(16.8)*	197 (14.7) *(14.7)*	33%[g]
Intermediate	407 (16.9) *(17.0)*	308 (16.0) *(16.0)*	200 (14.9) *(14.9)*	18%
Higher	1515 (63.1) (*63.3*)	1294 (67.0) *(67.2)*	942 (70.1) *(70.4)*	49%
Not known	8 (0.3)	6 (0.3)	4 (0.3)	
Age at twins' birth (years)				
Mother	33.6 (5.19)	33.4 (5.04)	33.6 (4.77)	29.5[a]
Father	36.4 (6.20)	36.1 (6.10)	36.1 (5.85)	-
BMI (kg/m^2)				
Mother	25.1 (4.82)	25.0 (4.71)	24.8 (4.51)	26.8[b]
Father	26.4 (3.94)	26.3 (3.90)	26.3 (3.77)	27.1[b]
Mothers eating '5 a day'[e]				
Yes	790 (32.9) *(33.2)*	671 (34.7) (*35.1)*	461 (34.3) *(34.6)*	31.0[b]
No	1587 (66.1) *(66.8)*	1243 (64.4) *(64.9)*	871 (64.9) *(65.4)*	69.0
Not known	25 (1.0)	17 (0.9)	11 (0.8)	
Fathers eating '5 a day'[e]				
Yes	663 (27.6) *(29.3)*	526 (27.2) *(29.2)*	376 (28.0) *(29.8)*	27.0[b]
No	1600 (66.6) *(70.7)*	1276 (66.1) *(70.8)*	886 (66.0) (70.2)	73.0
Not known	139 (5.8)	129 (6.7)	81 (6.0)	

[a] Office for National Statistics (2006). ONS Population report for England and Wales. Statistics correspond to parents with life births in 2006

[b] Health Survey for England 2007. (2008). Volume 1. Health lifestyles: knowledge, attitudes and behaviour. Ed R. Craig & N. Shelton. The health and social care Information Centre.

[c] Office for National Statistics (2008). General Household Survey 2007. Data for Great Britain in persons 16 and over.

[d] Italicized percentages are the valid percentages which may be compared to national statistics; non-italicized percentages include missing data. Percentages may not add up to 100 due to rounding.

[e] Consumption of at least 5 portions of fruit and vegetables per day.

[f] Department for Innovation, Universities and Skills. (2008). The level of highest qualification held by adults: England 2007. The education levels published in this report correspond roughly to the categories measured in Gemini, specifically from lowest to highest they include: no qualifications; GCSEs, an Intermediate GNVQ, two AS-levels, NVQs at levels 1 & 2, BTEC general certificates, YT certificates, other RSA certificates or other City and Guilds certificates; 2 A-Levels, 4 AS-Levels, an advanced GNVQ or NVQ level 3; foundation or first degrees, recognised degree level professional qualifications, NVQ level 4, teaching or nursing qualifications, HE diploma, HNC/HND or equivalent; postgraduate level qualifications and NVQ level 5.

[g] Office for National Statistics (2003). Socioeconomic classification of working-age population, summer 2003: Regional Trends 38.

4.4. Discussion

Gemini is an ideal data set with which to investigate the development of food preferences in early childhood. In particular, the sample allows for the exploration of individual differences in food preferences, and related characteristics, at two important developmental stages; 15 months (T1) before the age at which neophobia and food fussiness are generally considered to have emerged, and at 3 years when more selective preferences have developed and fussiness is relatively common.

The collection of multiple food-related psychometric measures in this cohort allows for the detailed measurement of preferences for specific types of foods and related eating behaviours. The repetition of these measures at different ages within the cohort further allows for longitudinal comparisons to explore the development of these traits over time.

As a large population-based cohort of infant twins, Gemini will also allow investigations of the relative environmental and genetic influences on food preferences and food fussiness. The large size of the cohort, and acceptable rates of attrition in later phases of data collection, permits small associations to be detected, and allows heritability estimates for food preferences to be computed with some reliability. The fact that the questionnaire used to establish the zygosity of the Gemini twins was found to be 100% accurate in classifying pairs as MZ or DZ in the sample validated using DNA is extremely reassuring and indicates that quantitative genetic analyses can be conducted and the findings interpreted with confidence.

The large number of sociodemographic, anthropometric and dietary-related variables included in the multiple phases of data collection allow for detailed cross-sectional and longitudinal comparisons. Although the sample is slightly healthier and of a higher social class than the wider population, and these differences are magnified in the later phases of data collection, there are nevertheless considerable variations in each of the sample characteristics measured, allowing for these differences in characteristics to be taken into account where appropriate. The Gemini twins were comparable to national twin statistics on all tested demographics in the baseline, T1 and T5 samples. However, it is important to note that twins tend to be born somewhat earlier than singletons (indicated by the mean gestational age), have smaller birth weights and are more susceptible to feeding problems. Although these factors are not the primary focus of this thesis, they will need to be taken into consideration when generalising findings to the wider population.

CHAPTER 5 . STUDY 1: PATTERNS OF FOOD PREFERENCE IN THE GEMINI COHORT

5.1. Background

As described in Chapter 1, food preferences are highly predictive of intake and it is therefore important to understand how these preferences develop over time. To date, few studies have systematically investigated the longitudinal development of food preferences during childhood. Studies have generally focussed on older children and little attention has been paid to food preferences in late infancy. The first years of life are a critical time for expanding children's food repertoires, with the number of new foods tried expanding rapidly. Given that neophobic and fussy traits start to emerge during the second year of life and have a negative impact on food acceptance, a better understanding of the patterns and development of food preferences in very early childhood could inform the development of interventions to promote healthy food choice.

Much research into food preferences focuses on individual foods or even single tastes, such as sweetness or bitterness. However examining liking for individual foods is not particularly enlightening as generalisations to broader dietary patterns cannot be made, while grouping foods based on their flavour properties does not necessarily provide the best explanation of patterns of food preferences (Wardle, Sanderson, et al., 2001). One method of examining how preferences for different commonly consumed foods cluster together within a population is to use factor-analytic procedures to explore the structure of liking for multiple individual food items. This methodology has previously been used to investigate patterns of food consumption in adult (Gittelsohn et al., 1998) and paediatric (North & Emmett, 2000) populations. Factor-analytic procedures have also been used in a study of patterns of food preferences in four to five year old children which found that the underlying structure of preferences was broadly consistent with traditional food categories ('Vegetables', 'Fruit', 'Meat and Fish' and 'Desserts') rather than with the sensory properties of individual foods (Wardle, Sanderson, et al., 2001). However there were some anomalies (e.g. ice cream loaded onto the 'Fruit' factor) and the findings have not been replicated in other samples.

Research examining food preferences across different age ranges is rare. One small (n=70) longitudinal study measuring food preferences in children between two and eight years, suggested that the number of foods disliked, along with the number of foods tried increased with age but interestingly not the number of foods liked (Skinner, Carruth, Bounds, et al., 2002). Additionally, longitudinal changes suggested that foods introduced after the age of four were more often disliked than liked. However a subsequent cross-sectional study of children's preferences found that controlling for the number of foods tried eliminated the age-related increase in number of foods disliked, suggesting it is merely an outcome of having more foods to rate (Cooke & Wardle, 2005). Interestingly, this same study found that the number of foods liked actually decreased with age as a function of the number tried. A cross-sectional study of food preferences in Australian preschool children reported no significant age differences in mean liking for food groups between two and five year olds. However differences in the number of disliked foods approached significance with five year olds disliking more foods than two year olds (Russell & Worsley, 2007). These studies provide some evidence for an age-related decrease in children's food acceptance. However the results are not conclusive and children's food preferences prior to the age of two have been largely ignored.

In order to develop effective interventions targeting the modification of food preferences, it is important to further understand how preferences for different individual foods cluster together in early childhood and how preferences track over time. The present study will examine the factorial structure of food preferences and explore developmental changes in preferences in a longitudinal cohort of twin children at two ages, 15 months and 3 years. On the basis of previous research it is expected that the pattern of children's preferences will align with traditional food categories and that these preferences will not be consistent with a healthy nutrient-rich diet. Specifically, it is predicted that vegetables will be among the least liked foods and that liking for energy-dense snack foods will be high at both ages.

5.2. Study aims

This study explores children's food preferences at 15 months (T1) and 3 years of age (T5). The factorial structure of food preferences at 3 years will be investigated to further understanding of the patterning of food preferences in young children and whether these cluster together in traditional food categories. Preferences for the food groups derived from these analyses will then be compared both cross-sectionally and longitudinally between 15 months (T1) and 3 years (T5).

5.3. Methods

5.3.1. Sample

The sample for this study was the Gemini cohort at T1 (n=3862) and T5 (n=2686). The characteristics of the cohort at these two time points have been described in detail in Chapter 4. Longitudinal comparisons included families who completed both T1 and T5 questionnaires (n=2570 children). At both time points, just under half of the children were male; T1 (n=1914, 49.6%) and T5 (n=1332, 49.6%).

5.3.2. Measures

The T1 Questionnaire was completed by Gemini parents when their twins were a mean age of 15.8 months (SD= 1.2, range=14.0-27.4). The full questionnaire is presented in Appendix 1.7. The T5 Questionnaire was completed by Gemini parents when their twins were on average 3.5 years of age (SD= 0.27, range=2.9 – 5.0). The full questionnaire is presented in Appendix 1.8.

5.3.2.1. T1 Food preference items

The Gemini T1 booklet included an 18 item food preference questionnaire (FPQ) in which families were asked 'How much do your twins like the following foods at the moment?**'** Parents were asked to provide an answer for both the '1st born' and '2nd born' twin with the response options; 'has never tried', 'dislikes a lot', 'dislikes', likes' and 'likes a lot'. 'Has never tried' was recoded to missing and remaining responses were scored as -2, -1, 1 and 2 respectively, to match scoring of food preferences at T5 (see below). Negative scores indicate that the food is disliked, while positive scores indicate the food is liked.

The foods included in the T1 FPQ were more limited and generalised in comparison to the T5 FPQ, which was completed by Gemini families when the twins were on average 3 years of age (the T5 FPQ is described in detail below). For example all dairy foods were grouped into a single item 'Dairy products (e.g. milk, cheese, yoghurt)' for the T1 FPQ, whereas individual foods were listed separately in the T5 FPQ. This is partly because the T1 questionnaire booklet covered a variety of extensive topics related to infant growth and appetite and therefore space was restricted. However, the choice of items also resulted from the fact the twins were only 15 months old at the time of questionnaire completion and dietary variety was expected to be more limited in this age group.

5.3.2.2. T5 Food preference items

The Gemini T5 booklet focussed almost exclusively on food preferences and food fussiness. The 114 item T5 food preference questionnaire (FPQ) asked families 'How much do your twins like the following foods at the moment?' Parents were asked to provide an answer for each twin, this time with 6 response options including; 'has never tried', 'dislikes a lot', 'dislikes', 'neither likes nor dislikes', 'likes' and 'likes a lot'. 'Has never tried', was recoded to missing and remaining responses were scored -2, -1, 0, 1, and 2.

The list of foods included in the T5 FPQ was based on a previous questionnaire used to examine the developmental patterning of food preferences in British schoolchildren (Cooke & Wardle, 2005). This in turn had been adapted from a questionnaire used to examine the factor-analytic structure of food preferences in the Twins Early Development cohort (TEDS) in 2001 (Wardle, Sanderson, et al., 2001). The parent-report procedure for obtaining children's food preferences has been shown to be adequate and reliable (Pliner & Pelchat, 1986).

For the T5 FPQ some small amendments were made to existing items; multiple ingredient dish items (e.g. lasagne, sausage rolls etc.) were removed because they were not thought to provide meaningful information on individual preferences. Moreover, both raw and cooked variants of several vegetables were added separately (e.g. cooked carrots and raw carrots) because culinary preparation methods affect the taste and texture of some vegetables which may in turn influence children's preference for them.

Drinks were excluded from the T5 FPQ because different factors may contribute to drink and food preferences. For example, there is evidence to suggest liking for carbonated drinks that contain caffeine may in part result from a reinforcement of preference based on physical dependence (i.e. the negative effects of caffeine withdrawal experienced when regular consumption is interrupted) (Garrett & Griffiths, 1998). For a full list of food items included in the T5 FPQ see Appendix 1.8.

5.3.3. Statistical analyses

All analyses were performed in SPSS Version 20 for Windows.

5.3.3.1. Assessing the factor structure of the T5 food preference questionnaire

Principal components analysis was used to examine the inter-relationships between the food items included in the T5 FPQ. Only food items that had been tried by at least 75% of the children in the sample were included in the principal component analysis (PCA).

5.3.3.1.1. Principal component analysis

Previous studies have used factor-analytic techniques to examine the factorial structure that emerges from food preference questionnaires in both adult (Gittelsohn et al., 1998) and child samples (North & Emmett, 2000; Wardle, Sanderson, et al., 2001). Given the younger sample (3 year old children), the extended number of food items and the modified food items included in the T5 FPQ compared to earlier versions, and the increased sample size of the present study, an exploratory method of analysis was deemed appropriate rather than a confirmatory method to establish whether the items loaded onto previously defined or theoretically constructed subscales of food groups. Two approaches can be used to explore the properties of a new scale, or a scale that has been used in a new population, these are factor analysis and principal component analysis (PCA) (Field, 2009). PCA was chosen as it is considered a psychometrically sound procedure and it is mathematically and theoretically less complex compared to factor analysis (Stevens, 1996).

5.3.3.1.2. Extraction of factors

In essence, PCA condenses multiple correlated variables into a smaller number of common components or factors that explain as much of the variation as possible, while maintaining as much information as possible. This is done by calculating common variance shared between variables using a correlation coefficient matrix. PCA calculates all of the possible linear combinations of variables and extracts the component that represents the variable combination describing the optimal amount of the original variation: i.e. the linear combination with the largest sample variance. All successive components are extracted using the same method and subsequent factors are identified as the variable combination explaining the maximum amount of the residual variance. The amount of total variance that each factor explains is denoted by its eigenvalue. Higher eigenvalues indicate a larger amount of variance in the data is explained by that factor and are indicative of the factor's importance. Ultimately, only factors with relatively large eigenvalues should be selected.

Several methods are used in the process of factor selection: a scree plot presents the eigenvalues of each factor graphically in size order and illustrates cut-offs (sharp points of inflection or the ‘elbow shape’ in the graph) that can be used when selecting the most important factors (Cattell, 1966). In addition, Kaiser (Kaiser, 1960) recommended retaining all factors with eigenvalues greater than 1 as this represents a substantial amount of variation. However Field (Field, 2009) suggests Kaiser’s criterion is only accurate when there are less than 30 variables and communalities after extraction are <0.7 or when the sample size exceeds 250 and the average communality is <0.6. For the purposes of analysing the T5 FPQ, examination of the scree plot was primarily used when determining the number of factors extracted as 84 variables were included in the PCA, and despite the large sample size (2686) the average communality was only 0.3.

5.3.3.1.3. Rotation method

In PCA, the majority of items tend to load highly onto the most important factor and therefore a technique called rotation is used. Rotation maximises the loadings of the items onto different factors and aims to balance the relative importance of each factor, without effecting the underlying solution (Field, 2009). There are two types of rotation techniques; ‘orthogonal’ and ‘oblique’ rotation. ‘Orthogonal’ rotation assumes the factors do not correlate. In contrast, the ‘oblique’ method allows factors to inter-correlate. For the PCA of the T5 FPQ an oblique (‘direct oblimin’) rotation method was chosen as food group preferences could be related in theoretical terms (Field, 2009), and have been shown to inter-correlate in previous research.

The oblique rotation method generates two factor matrices; (1) the Pattern matrix, containing the factor loadings including the unique contribution of each item to each factor, and (2) the structure matrix which also takes into account factor inter-correlations when estimating the contribution of each item to each factor. As values in the pattern matrix could potentially be suppressed when factors are correlated with one another, the structure matrix can be used to verify the factors and therefore results from both matrices were considered (Graham, Guthrie, & Thompson, 2003).

5.3.3.1.4. Choice of factor-loading value

In interpreting the structure matrix, a food item was considered to load onto a factor if its loading score was ≥0.4 on that factor (items explaining approximately 16% of the variance in the factor) (Stevens, 1996) but also <0.4 on all the other 4 factors in the matrix (Munro, 2005). However, all item loadings were generated to understand smaller relationships between all of the items and all factors.

5.3.3.1.5. Missing data

Pairwise deletion of missing cases was used as this method retains all cases with any data and provides a reasonable solution with large datasets and relatively few missing values (Tabachnick & Fidell, 2001).

5.3.3.1.6. Reliability analysis

It is important to check the reliability of the subscales identified through PCA. The most common measure of scale reliability is Cronbach's Alpha (α) (Field, 2009) and this method was used to test the internal reliabilities of the T5 FPQ subscales derived from the PCA. Ideally, the α value should be greater than 0.7, with values below this indicating an unreliable scale. However, the α value is also dependent upon the number of items in a scale and as the number of items increases the α increases (Cortina, 1993).

5.3.3.2. Scale scores

5.3.3.2.1. T5 Food preference scale scores

Individual scores were calculated for each child for each of the derived food group subscales identified through the PCA and reliability analysis. This was done by summing all of the available item scores within each subscale and dividing the total value by the number of completed items. Participants were required to have completed a minimum of 60% of items in order for subscale score to be calculated.

5.3.3.2.2. T1 Food preference scale scores

In order to make comparisons between the two data collection phases (T1 and T5), food items from the T1 FPQ were categorised into groups comparable to the subscales that emerged from the PCA of the T5 FPQ. The items included in these scales are described below. Scale scores were either derived from single items or from the mean of two items. Participants were required to have completed a minimum of 50% of items in order for subscale score to be calculated.

5.3.3.3. Summary statistics

Means and standard deviation scores as well as medians and interquartile ranges were calculated for the food group scales at T1 and T5. Skewness and Kurtosis statistics, along with the Kolmogorov–Smirnov (K-S) test, were calculated to check if the distribution of scale scores in the T1 and T5 samples differed significantly from a normal distribution. The K-S test showed the distribution of each of the FPQ scales to be significantly non-normal ($p<0.01$) and skewness scores suggested some negative skew for many of the scales. However, examination of the histograms was not conclusive and Field (2009) warns that in large samples tests of normal distribution can be significant even when the scores are only slightly different from a normal. Therefore, both parametric and non-parametric tests were run for all analyses, but as results were similar only parametric statistics are reported.

Pearson's Product Moment correlation coefficients and Spearman's Rho were both calculated to assess bivariate relationships between the FPQ and FF scales. As both these methods produced similar results, only the Pearson's correlations are presented. A Pearson's correlation of ± 0.1 represent a small effect, ± 0.3 is a medium effect and ± 0.5 is a large effect (Field, 2009). For all analyses an alpha level of 0.01 was selected for significance to reduce the risk of a Type 1 error resulting from the large sample and multiple tests.

5.4. Results

5.4.1. Results of the principal components analysis for T5 food preferences

5.4.1.1. Data screening

The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was 0.887 which is classified as 'great' (Hutcheson & Sofroniou, 1999) and the KMO value for every individual variable was >0.75 which is well above the acceptable limit of 0.5 (Field, 2009). No variables in the correlation matrix correlated too highly (all <0.7) and Bartlett's Test of Sphericity χ^2 (3570) = 43553.705, $p<0.0001$, indicated that correlations between items were sufficiently large for PCA. Only 20% of the reproduced residuals had absolute values greater than 0.05 indicating that the model fitted the data well (Field, 2009).

5.4.1.2. The factor structure of the T5 food preference questionnaire

Of the 114 foods items listed in T5 FPQ, 30 foods had been tried by less than 75% of the sample and were therefore excluded from the PCA. These excluded foods were generally sophisticated (e.g. pate, seafood, soft cheese) or uncommon and/or not native to the UK (e.g. okra, yams, papaya). These 30 excluded foods were liver, pate, oily fish, seafood, pulses, nuts, fried eggs, cottage cheese, soft cheese, sugared cereals, runner beans, leeks, pumpkin, swedes, beetroot, aubergine, okra, mangetout, sugarsnap peas, celery, spinach, yams, plantain, avocado, apricot, fig, pomegranate, papaya, cherries and grapefruit. The remaining 84 foods were included in the PCA. Examination of the scree plot suggested restricting the PCA to five factors. The five factors within the dataset had eigenvalues of 11.92 (Factor 1), 3.96 (Factor 2), 2.60 (Factor 3) and 2.18 (Factor 4) and 4.61 (Factor 5)[13].

As values in the Pattern matrix can be suppressed if factors are correlated (Graham et al., 2003), the Structure matrix is presented here (see Table 5.1). In interpreting the structure matrix, a food item was considered to load onto a factor if its loading score was ≥0.4 on that factor but also <0.4 on all the other 4 factors in the matrix (Munro, 2005). In total, 23 food items failed to load at 0.4 or above onto any of the factors. Of the 61 food items that successfully loaded onto the 5 factors, 2 foods (ice lollies and cucumber) loaded highly onto 2 factors and were therefore excluded. This provided 5 meaningful factors comprising of 59 foods in total. Inspection of the factors indicated five distinct food groups (see Table 5.2). The first factor included 16 food items, all of which were vegetables. The second factor represented liking for fruit and included 15 food items. Interestingly fresh tomatoes which (although botanically categorised as a fruit) are generally considered vegetables for culinary purposes, loaded onto the fruit factor for liking. The third factor comprised of 9 protein foods, including a variety of meats and also whitefish. The fourth factor included 10 egg and dairy foods, comprising of; 2 egg items, 3 cheese items, cream, butter, margarine, mayonnaise and custard. The fifth and final factor was made up of 9 ‘snack’ food items including a combination of sweet (e.g. chocolate biscuits, cakes, ice cream) and savoury (e.g. crisps and chips) snack foods

5.4.1.3. Reliability analyses

Cronbach’s alphas were calculated for the five food group subscales identified in the PCA. All scales were internally reliable: ‘vegetables’, α=0.87 (16 items); ‘fruit’, α=0.88 (15 items); ‘protein’, α =0.78 (9 items); ‘dairy’, α=0.72 (10 items); ‘snacks’, α=0.72 (9 items).

---

[13] The order of the five factors has been rearranged in keeping with the focus of the current thesis. The original order produced by the PCA conducted in SPSS was arranged in order of the magnitude of the eigenvalues (i.e. largest to smallest).

Table 5.1: Factor structure of food item preference scores (T5)

Food item	Component				
	1	**2**	**3**	**4**	**5**
Cabbage	**.709** [a]	-.234	-.213	-.151	-.045
Broccoli	**.665** [a]	-.213	-.230	-.155	.003
Cauliflower	**.656** [a]	-.181	-.179	-.208	-.009
Green beans	**.655** [a]	-.314	-.204	-.083	-.026
Peas	**.609** [a]	-.214	-.197	-.101	.072
Cooked peppers	**.594** [a]	-.242	-.185	-.169	.013
Sprouts	**.578** [a]	-.200	-.175	-.143	-.063
Cooked carrots	**.547** [a]	-.217	-.145	-.184	.120
Salad	**.535** [a]	-.284	-.134	-.094	-.012
Parsnips	**.534** [a]	-.189	-.225	-.137	.029
Raw peppers	**.533** [a]	-.308	-.092	-.037	-.010
Sweet potatoes	**.517** [a]	-.156	-.251	-.281	.086
Sweetcorn	**.491** [a]	-.301	-.206	-.153	.070
Cucumber	**.482** [b]	**-.408** [b]	-.128	-.028	-.022
Raw Carrots	**.479** [a]	-.340	-.103	-.072	.081
onions	**.432** [a]	-.131	-.237	-.161	-.060
Potatoes	**.414** [a]	-.034	-.305	-.286	.209
Mushrooms	.389	-.196	-.230	-.239	-.049
Roast potatoes	.381	-.073	-.322	-.181	.334
Tinned tomatoes	.291	-.137	-.243	-.264	.123
Baked Beans	.268	-.106	-.182	-.262	.192
Peaches	.316	**-.721** [a]	-.164	-.222	.066
Oranges	.221	**-.706** [a]	-.188	-.149	.081
Tangerines	.210	**-.705** [a]	-.171	-.117	.063
Plums	.363	**-.702** [a]	-.193	-.193	.079
Grapes	.244	**-.650** [a]	-.096	-.072	.091
Strawberries	.230	**-.649** [a]	-.182	-.146	.127
Pears	.277	**-.629** [a]	-.164	-.186	.096
Raspberries	.242	**-.599** [a]	-.169	-.173	.106
Blueberries	.315	**-.585** [a]	-.150	-.131	.060
Pineapple	.308	**-.568** [a]	-.110	-.194	.138
Mango	.258	**-.541** [a]	-.098	-.122	.067
Raw apples	.231	**-.540** [a]	-.092	-.075	.090
Kiwi	.290	**-.529** [a]	-.124	-.205	.030
Melon	.310	**-.525** [a]	-.107	-.203	.070
Fresh tomatoes	.386	**-.453** [a]	-.142	-.149	-.034
Bananas	.099	-.392	-.061	-.199	.156
Baked apples	.256	-.328	-.132	-.323	.193
Raisins	.137	-.323	-.138	-.162	.199
Beef	.260	-.123	**-.748** [a]	-.150	.035

Pork	.202	-.140	**-.716** [a]	-.147	.055
Lamb	.219	-.165	**-.707** [a]	-.162	.068
Chicken	.207	-.078	**-.695** [a]	-.105	.073
Turkey	.199	-.045	**-.627** [a]	-.159	.075
Beef burger	.152	-.136	**-.533** [a]	-.133	.143
Ham	.141	-.112	**-.510** [a]	-.247	.063
Bacon	.150	-.201	**-.488** [a]	-.117	.088
whitefish	.335	-.113	**-.401** [a]	-.332	-.027
Sausages	.132	-.055	-.398	-.092	.187
Rice	.338	-.073	-.355	-.253	.086
Nuggets	.062	.049	-.333	-.143	.287
Battered Fish	.230	.040	-.298	-.229	.236
Cream	.115	-.124	-.124	**-.527** [a]	.248
Eggs	.171	-.230	-.215	**-.527** [a]	-.041
Butter	.037	-.010	-.142	**-.525** [a]	.256
Margarine	.048	.001	-.126	**-.517** [a]	.320
Scrambled eggs	.187	-.179	-.218	**-.513** [a]	-.046
Processed cheese	.074	-.121	-.086	**-.509** [a]	.096
Cream cheese	.135	-.081	-.130	**-.500** [a]	.113
Hard cheese	.126	-.107	-.159	**-.490** [a]	.167
Mayonnaise	.176	-.146	-.157	**-.464** [a]	.104
Custard	.153	-.176	-.129	**-.449** [a]	.308
Porridge	.209	-.211	-.144	-.385	.090
Tuna	.290	-.126	-.326	-.329	-.020
Jam	.088	-.291	-.075	-.303	.288
Pasta	.246	-.102	-.206	-.287	.074
Other Cereals	.202	-.105	-.115	-.215	.207
Chocolate biscuit	-.033	-.111	-.072	-.134	**.639** [a]
Cakes	-.016	-.145	-.130	-.188	**.622** [a]
Chocolate	-.074	-.077	-.071	-.078	**.557** [a]
Plain biscuits	-.019	-.086	-.056	-.173	**.548** [a]
Buns	.076	-.246	-.161	-.339	**.531** [a]
Crisps	.031	-.071	-.113	-.071	**.498** [a]
Ice Cream	.011	-.251	-.088	-.154	**.474** [a]
Ice Lollies	.015	**-.403** [b]	-.139	-.140	**.473** [b]
Chips	.216	-.032	-.220	-.143	**.442** [a]
White Bread	.027	.027	-.063	-.163	**.403** [a]
Dairy Deserts	.046	-.202	-.033	-.341	.376
Savoury Snacks	.088	-.022	-.060	-.200	.373
Sweets	.024	-.356	-.112	-.117	.366
Ketchup	.101	-.150	-.080	-.211	.282
Brown Bread	.205	.026	-.115	-.115	.280
Yoghurt	.030	-.114	-.026	-.208	.268
Pizza	.126	-.091	-.202	-.158	.242

[a] Items loading above .4 on a single component (**bolded**).
[b] Items loading above .4 on more than one component.

Table 5.2: T5 food preferences, factor loadings and Cronbach's alphas for the 59 items that loaded on one of the five factors

Scale Items	**Children who have tried food** N (%)	**Preference[a] score** Mean (sd)	**Factor Loadings**	**Cronbach's alpha**
Vegetables (16 items)	*2639 (98.3)*	*0.47 (0.62)*		**0.87**
Cabbage	2417 (90.0)	0.06 (1.13)	.71	
Broccoli	2660 (99.1)	0.78 (1.19)	.67	
Cauliflower	2584 (96.3)	0.24 (1.12)	.66	
Green beans	2541 (94.7)	0.41 (1.16)	.66	
Peas	2667 (99.3)	1.02 (1.02)	.61	
Cooked peppers	2445 (91.0)	0.14 (1.06)	.59	
Sprouts	2112 (78.6)	-0.29 (1.20)	.58	
Cooked carrots	2674 (99.6)	1.17 (0.97)	.55	
Salad	2482 (92.4)	-0.73 (1.16)	.54	
Parsnips	2303 (85.8)	0.20 (1.04)	.53	
Raw peppers	2277 (84.8)	0.07 (1.24)	.53	
Sweet potatoes	2272 (84.5)	0.52 (0.93)	.52	
Sweetcorn	2627 (97.8)	1.00 (1.05)	.49	
Raw carrots	2588 (96.4)	0.86 (1.13)	.48	
Onions	2580 (96.1)	0.17 (0.92)	.43	
Potatoes	2679 (99.8)	1.03 (1.00)	.41	
Fruit (15 items)	*2598 (96.7)*	*0.91 (0.69)*		***0.88***
Peaches	2421 (90.2)	0.84 (1.07)	-.72	
Oranges	2613 (97.3)	1.05 (1.10)	-.71	
Tangerines	2606 (97.0)	1.15 (1.09)	-.71	
Plums	2318 (86.3)	0.68 (1.10)	-.70	
Grapes	2660 (99.0)	1.58 (0.84)	-.65	
Strawberries	2663 (99.1)	1.43 (0.99)	-.65	
Pears	2590 (96.5)	1.03 (1.00)	-.63	
Raspberries	2452 (91.3)	0.93 (1.18)	-.60	
Blueberries	2218 (82.6)	0.92 (1.20)	-.59	
Pineapple	2410 (89.4)	0.57 (1.15)	-.57	
Mango	2083 (77.6)	0.60 (1.08)	-.54	
Raw apples	2666 (99.3)	0.53 (0.75)	-.55	
Kiwi	2164 (80.6)	0.39 (1.20)	-.53	
Melon	2522 (93.9)	0.80 (1.16)	-.53	
Fresh tomatoes	2618 (97.4)	0.19 (1.38)	-.45	
Protein (9 items)	*2542 (94.6)*	*0.85 (0.59)*		***0.78***
Beef	2493 (92.8)	0.74 (0.95)	-.75	
Pork	2220 (82.3)	0.62 (0.90)	-.72	
Lamb	2136 (79.5)	0.64 (0.94)	-.71	
Chicken	2608 (97.1)	1.31 (0.82)	-.70	

Turkey	2292 (85.3)	0.87 (0.80)	-.63	
Beef burger	2064 (76.8)	0.45 (1.02)	-.53	
Ham	2540 (94.5)	1.15 (1.01)	-.51	
Bacon	2221 (82.7)	0.85 (1.05)	-.49	
White fish	2402 (89.6)	0.88 (0.91)	-.40	
Dairy (10 items)	*2603 (96.9)*	*0.76 (0.59)*		***0.72***
Cream	2208 (82.2)	0.54 (1.00)	-.53	
Eggs	2544 (94.7)	0.63 (1.27)	-.53	
Butter	2546 (99.3)	1.21 (0.85)	-.53	
Margarine	2160 (80.4)	0.91 (0.90)	-.52	
Scrambled eggs	2497 (92.9)	0.45 (1.26)	-.51	
Processed cheese	2242 (83.4)	0.60 (1.24)	-.51	
Cream cheese	2061 (76.7)	0.61 (1.04)	-.50	
Hard cheese	2646 (98.5)	1.26 (0.99)	-.49	
Mayonnaise	2035 (75.8)	0.32 (1.12)	-.46	
Custard	2521 (93.9)	0.94 (1.07)	-.45	
Snacks (9 items)	*2674 (99.6)*	*1.42 (0.41)*		***0.72***
Chocolate biscuit	2652 (98.8)	1.64 (0.65)	.64	
Cakes	2674 (99.6)	1.38 (0.78)	.62	
Chocolate	2669 (99.4)	1.70 (0.78)	.56	
Plain biscuits	2670 (99.4)	1.50 (0.61)	.55	
Buns	2524 (94.0)	1.00 (0.94)	.53	
Crisps	2651 (98.7)	1.61 (0.62)	.50	
Ice cream	2660 (99.0)	1.51 (0.83)	.47	
Chips	2669 (99.4)	1.23 (0.81)	.44	
White bread	2635 (98.1)	1.18 (0.70)	.40	

[a] Higher scores indicate higher liking

5.4.2. T1 food preference scales

In order to make longitudinal comparisons between the T1 and the T5 questionnaires, 5 comparative food group liking scores were also calculated for the T1 FPQ, these were labelled: vegetables, fruit, protein, dairy and snacks. The vegetable and fruit scales were based on single questionnaire items. Protein was based on two items; ‘meat (e.g. chicken, lamb, pork beef)’ and ‘Fish (fresh, frozen, tinned or fish fingers)’. Dairy was based on one item; ‘dairy products (e.g. milk, cheese, yoghurt)’. Finally, snacks was also based on two items; ‘Savoury snacks (e.g. crisps, cheese biscuits)’ and ‘Sweet snacks (e.g. cakes, biscuits, ice cream)’.

5.4.3. Summary statistics

5.4.3.1. T1 food preference questionnaire; summary statistics and comparisons

The mean and median preference scores for all of the five food groups were towards the positive ‘liking’ end of the scale at T1 (see Table 5.3). The lowest mean preference score was for protein, followed by vegetables and snacks. The highest mean preference score was for dairy, with fruit as the second highest. Median scores followed a similar pattern with protein and vegetables displaying the lowest median preference score and dairy and fruit with the highest median preference scores. Paired samples t-tests comparing mean preference scores between all the food groups at T1 revealed that all the scores were significantly different from one another ($p<0.01$). Non-parametric related samples Wilcoxon’s-signed rank test also revealed significant group differences in preference scores for all food group combinations ($p<0.01$) with the exception of vegetables and snack foods, for which the median preference scores were not significantly different.

Preference scores for all five food groups at T1 were positively correlated with one another (Table 5.5). The majority of these correlations were in the range of 0.1 and therefore represented a relatively small effect. However preference for vegetables correlated more strongly with preferences for both fruit and protein ($r > 0.3$). Table 5.3 presents the individual items included in the T1 food preference scales. The response options for the T1 questionnaire were on a 4 point scale with the same labels as the T5 questionnaire (‘dislikes a lot’, ‘dislikes’, ‘likes’ and ‘likes a lot’) but no middle neutral response-option (i.e. no ‘neither likes nor dislikes’). Therefore, scales do not fully correspond across the two questionnaires, but for ease of comparison the same numerical scores were attributed to the T1 and T5 response options (i.e. ‘dislikes a lot’=-2, ‘dislikes’=-1, ‘likes’ = 1 and ‘likes a lot’=2) and ‘0’ scores (‘neither likes not dislikes’) were simply omitted from the T1 food preference scales. As a result of this, both parametric and non-parametric descriptive statistics will be reported to allow for the unequal intervals in the T1 scale data.

Table 5.3: T1 food preferences scale items and scores

Scale items	Have tried food	Preference score[a] (-2 to +2)	
	N (%)	Mean (sd)	Median (IQR)
Vegetables (1 item)	**3844 (99.5)**	**1.41 (0.71)**	**1.00 (1.00-2.00)**
Vegetables (uncooked, cooked or pureed, fresh, frozen or tinned)			
Fruit (1 item)	**3845 (99.6)**	**1.67 (0.58)**	**2..0 (1.00-2.00)**
Fruit (uncooked, cooked, pureed, fresh, frozen or tinned)			
Protein (2 items)	**3808 (98.6)**	**1.25 (0.65)**	**1.00 (1.00-1.88)**
Meat (e.g. chicken, lamb, pork, beef)	*3711 (96.1)*	*1.25 (0.72)*	*1.00 (1.00-2.00)*
Fish (fresh, frozen, tinned or fish fingers)	*3705 (95.9)*	*1.25 (0.85)*	*1.00 (1.00-2.00)*
Dairy (1 item)	**3822 (99.0)**	**1.81 (0.45)**	**2.00 (2.00-2.00)**
Dairy products (e.g. milk, cheese, yoghurt)			
Snacks (2 items)	**3709 (96.0)**	**1.44 (0.53)**	**1.50 (1.00-2.00)**
Sweet snacks (e.g. cakes, biscuits, ice cream)	*3609 (93.4)*	*1.46 (0.63)*	*2.00 (1.00-2.00)*
Savoury snacks (e.g. crisps, cheese biscuits)	*3205 (83.0)*	*1.43 (0.59)*	*1.00 (1.00-2.00)*

[a] Higher scores indicate higher liking

5.4.3.2. T5 food preference questionnaire; summary statistics and comparisons

The mean liking scores for each of the 54 individual foods that comprised the five food groups at T5 are shown in Table 5.2. The three least liked foods were vegetables and included; salad (mean=-0.73), brussels sprouts (mean=-0.29) and cabbage (mean=0.06). While the most liked foods were snack foods; chocolate (mean=1.70), chocolate biscuits (mean=1.64) and crisps (mean=1.61). The mean preference scores for all 84 individual foods measured at T5 and tried by at least 75% of children, including those that were not grouped in the PCA, are shown in Appendix 2.2.

At T5, the mean preference scores for each of the food groups were below 1 but above 0, with the exception of snack foods (mean=1.42) (see Table 5.4). Based on both mean and median preference scores vegetables were the least liked foods, followed by dairy, protein and fruits. As expected, snack foods had the highest mean (and median) preference scores at T5. Parametric and non-parametric paired samples tests (t-tests and Wilcoxon's-signed rank test) indicated that all the food group preference scores were significantly different from one another ($p<0.01$).

Bivariate correlations of all the five food groups at T5 showed preferences for each of the food groups to significantly positively correlate with one another (all p>0.01) (shown in Table 5.5). Vegetable and fruit liking correlated highly (r >0.5, which can be considered a large effect), while vegetables and protein, and dairy and snack food preferences also correlated relatively strongly (r >0.3).

Table 5.4: Descriptive statistics for the food preference scales at T1 and T5

FPQ Scales	Mean	SD	Median	IQR	N [a] (%)
Vegetables					
T1	1.41	0.71	1.00	1.00-2.00	3844 (99.5)
T5	0.47	0.62	0.53	0.10-0.88	2639 (98.3)
Fruit					
T1	1.67	0.58	2.00	1.00-2.00	3845 (99.6)
T5	0.91	0.69	1.00	0.54-1.40	2598 (96.7)
Protein					
T1	1.25	0.65	1.00	1.00-1.88	3808 (98.6)
T5	0.85	0.59	1.00	0.57-1.22	2542 (94.6)
Dairy					
T1	1.81	0.45	2.00	2.00-2.00	3822 (99.0)
T5	0.76	0.59	0.80	0.40-1.14	2603 (96.9)
Snacks					
T1	1.44	0.53	1.50	1.00-2.00	3709 (96.0)
T5	1.42	0.41	1.44	1.14-1.78	2674 (99.6)

[a] N refers to number of participants providing complete data from the full samples returning T1 and T5 respectively.

5.4.3.2. Longitudinal comparisons between food preferences at T1 and T5

The food group preference scores at T1 were compared with their corresponding preference scores at T5. As the T1 scales were slightly skewed, non-parametric Wilcoxon's-signed rank test were used to assess within-subject differences in median preference over time. Vegetables, fruit, protein and dairy food groups were all found to have significantly higher median preference scores at T1 compared to T5 (all p<0.001), indicating a decrease in liking for all of these food groups with age. However, no significant difference in snack food liking was found between the two time points.

Table 5.5: Pairwise correlation matrix showing the relationships between the FPQ scales at T1 and T5

	Correlation coefficient (N) [a]								
	T1 Veg	T1 Fruit	T1 Protein	T1 Dairy	T1 Snacks	T5 Veg	T5 Fruit	T5 Protein	T5 Dairy
T1 Fruit	.362** [b] (2552)								
T1 Protein	.312** [b] (2527)	.217** (2523)							
T1 Dairy	.114** (2544)	.170** (2542)	.097** (2517)						
T1 Snacks	.074** (2467)	.118** (2465)	.098** (2525)	.175** (2463)					
T5 Veg	.221** (2521)	.169** (2519)	.153** (2493)	.012 (2509)	.047 (2432)				
T5 Fruit	.177** (2479)	.301** [b] (2477)	.082** (2455)	.069** (2469)	.035 (2398)	.501** [b] (2578)			
T5 Protein	.145** (2428)	.130** (2426)	.239** (2431)	.010** (2420)	.043 (2348)	.343** [b] (2509)	.267** (2479)		
T5 Dairy	.072** (2484)	.090** (2482)	.125** (2458)	.143** (2482)	.087** (2407)	.260** (2569)	.273** (2536)	.296** (2478)	
T5 Snacks	.021 (2548)	-.098* (2548)	.083** (2519)	.067** (2538)	.239** (2461)	.068** (2629)	.207** (2598)	.158** (2532)	.306** [b] (2598)

** Correlations significant at an alpha level of <0.001.
[a] N refers to the number of participants in T5 sample who also provided data for the T1 questionnaire (maximum n=2686)
[b] Pearson Correlations above 0.3 (in **bold)**, suggesting a medium effect.

5.5. Discussion

5.5.1. Summary of findings

The PCA findings for the food preference questionnaire indicate that liking for individual foods are interrelated but only for a restricted number of foods. The results reflect the findings of earlier research, suggesting that preferences group together in traditional food categories (e.g. vegetables or fruits) (Wardle, Sanderson, et al., 2001) but the factors emerging from these analyses are even more clearly defined, in terms of the individual food item loadings, than those previously reported. For example, in the previous study, ice cream loaded onto the ‘fruit factor’ and melon loaded onto the ‘vegetable factor’ (Wardle, Sanderson, et al., 2001). In the present study, tomatoes, which are generally considered a vegetable in culinary terms, were the only item to load onto an arguably inappropriate factor in these analyses. In addition, a fifth factor emerged from the present research, compared to the four derived from the previous study. After vegetables, fruit and protein foods, the fourth food group emerging from the PCA in the earlier study was labelled ‘desserts’ and comprised cakes, custard and dairy desserts. In the present analyses, however, these types of food items loaded onto two separate components - ‘dairy’ and ‘snack’ foods. Interestingly ‘snack’ foods comprised both savoury (e.g. crisps) and sweet (e.g. cakes) snack foods confirming that food preferences do not cluster together according to simple taste characteristics such as sweetness or saltiness.

As predicted, the patterns of food preferences in this large cohort sample at 3 years were similar to those cited in multiple previous studies (Bellisle et al., 2000; Cooke & Wardle, 2005; Diehl, 1999; Skinner, Carruth, Bounds, et al., 2002). Vegetables were found to be the least liked food group and snack foods were the most liked. However, at 15 months of age food preferences were generally higher for all categories and vegetables were found to be preferred to protein foods and to not differ from snack foods in terms of mean preference. A positive finding is the comparatively high liking for fruit displayed by both age groups with fruit being the most liked food group at 15 months and the second most preferred at 3 years.

Preferences for each of the food groups decreased over time, with the exception of snack foods, for which liking remained high and stable between the two time points. These findings are comparable to those describing a decline in the number of foods liked as children get older (Cooke & Wardle, 2005) and supports the idea of a deterioration in dietary variety and quality in later childhood (Lytle et al., 2000). The largest drops in preference were for dairy foods and vegetables. This decrease in preference for dairy foods may reflect the decrease in consumption of milk and other dairy foods that occurs during the transition from infancy into childhood. The decline in liking for vegetables with age is concerning but not unexpected. Decreased preferences for vegetables may reflect age-related increases in neophobia and fussiness, given that these eating behaviour traits have been strongly associated with vegetable acceptance in previous research (Galloway et al., 2003; Jacobi et al., 2003). The findings of clear age-related differences in food preferences in the present study contrast with less consistent reports in the existing literature. Russell and Worsley (2007) reported few age differences in the food preferences of two and five year old Australian children but it is possible that as the youngest children in this study were two years old, food preferences may have already started to decline. Previous research has pointed towards infancy as a critical period for flavour acceptance and preferences may steeply decline in the transition from infancy to childhood, particularly in line with the onset of neophobic and fussy traits. In contrast there may be less change in liking for foods following infancy with preferences becoming more stable in the early childhood years.

However, it is also possible that the age-related differences in preference reported here in part reflect the different scales used at the two time points. Increased diversity in the diets of older children may be responsible for the age differences in food group preference score, but equally the single or double item scales used to measure preferences in the younger age group may have limited variation in response options resulting in inflated preference scores in this age group. For example the dairy category at 15 months may only have captured liking for milk, cheese and yoghurt (the examples provided in the questionnaire item), in comparison to the 10 item scale measured at 3 years.

5.5.2. Limitations

The analyses were in a very large population-based sample of children from across England and Wales but nevertheless some limitations of this study are acknowledged. The food group variables used in the T1 analyses, although similar to the food categories that emerged from the PCA of the T5 questionnaire, included few items and therefore were limited in detail. In contrast, the factor structure and internal reliability of the scales used from T5 were strong and included a large number of food items. It would have been inappropriate to administer an extensive food preference questionnaire (similar to the one completed at T5 in these analyses) to parents of 15 month old infants, as children of this age are unlikely to have tried such a wide variety of foods. However identical measures of food preferences at both time points would have strengthened the findings of this study. Future research would benefit from identifying specific food items most commonly consumed in both late infancy *and* early childhood and best reflect preferences for major categories of foods.

In addition, food preference questionnaire response options differed slightly between T1 and T5. At T1 there was no ‘neither likes nor dislikes’ option. Although all other options were identical at both time points, this may have contributed to differences in liking ratings between the two ages. At 15 months, parents would have been forced to identify their children’s more neutral responses to foods as either ‘likes’ or ‘dislikes’ which may have slightly distorted children’s preference scores. However the standard deviation scores for preferences at T1 and T5 are similar suggesting comparable responding at both time points.

There are also some shortcomings to the food preference measure used at T5. Although a large number of food items were included overall, the number of each type of food varied which may have influenced the factor structure that emerged. For example there were a large number of vegetables and fruits listed while other foods such as savoury snacks, plain biscuits and hard cheeses were listed as single items which does not reflect the variety of these foods available. However in order to rectify this it would have been necessary to extend the list of individual foods rendering the measure overlong and very time-consuming for parents to complete. These are problems inherent to using the ‘list heuristic’ to study food choice behaviours and have been discussed in detail elsewhere (Potts & Wardle, 1998).

The questionnaire measures used were parent-report and could be subject to bias. It is possible that because older children are more able to express their preferences verbally, parents would be better able to identify food dislikes when their children were 3 years than when they were 15 months. Although child reports of their own food preferences may provide more accurate results, these measures are also not without problems (Liem, Mars, & de Graaf, 2004), are time-consuming and impossible in children as young as 15 months. Parental reports of children's behaviours are frequently used in both behavioural and nutrition research (Wardle, Guthrie, Sanderson, & Rapoport, 2001) and maternal reports of children's food preferences have been shown to correlate highly with children's self-reported preferences (Skinner, Carruth, Wendy, et al., 2002). The parent-report procedure for obtaining children’s food preferences has been previously shown to be adequate and reliable (Pliner & Pelchat, 1986). Conclusions drawn from PCA are necessarily restricted to the specific sample collected (Field, 2009), and replication of the factor structure in other samples is needed to confirm the underlying dimensions of food preference categories emerging from the present analyses. Likewise, the reliability of a scale varies according to the sample being tested, making it important to repeat the analyses with other samples (Field, 2009).

5.5.3. Conclusion

The underlying structure of children's food preferences was found to reflect traditional food categories. Patterns of food preferences observed in the current study were not found to be consistent with a healthy diet. Children displayed high preferences for snack foods at both 15 months and 3 years and unlike other food categories, liking for snack foods did not decrease as children got older. More encouragingly, fruit was relatively well-liked at both ages. In contrast, vegetables were among the more disliked foods at both ages and liking decreased significantly between 15 months and 3 years. These findings suggest that interventions aimed at modifying food preferences should concentrate on vegetables and target fruit and vegetables separately. Taken together these findings are consistent with previous research that suggests that there is a need for early intervention to modify children's food preferences if healthier dietary patterns are to be achieved.

This study has produced five robust scales, providing measures of food preferences for a variety of nutrient-rich and energy-dense foods in three year old children (T5). The liking scores for the five food groups derived from these analyses will be used in the following chapters to answer several key questions of this thesis.

CHAPTER 6 . STUDY 2: FACTORS ASSOCIATED WITH FOOD PREFERENCES IN EARLY CHILDHOOD

6.1. Background

The literature reviewed in Chapter 1 suggests that there are multiple determinants of food preferences in early childhood (see Appendix 2.1. for a table summarising this literature). Aspects of the early family and home environment and characteristics of children themselves have been suggested as predictors of preferences, specifically for fruits and vegetables. However findings have been inconsistent and few studies have attempted to comprehensively investigate the familial, sociodemographic and child characteristics associated with preferences for both healthy and unhealthy foods in a single study. Given that the development of food preferences begins in very early childhood and the emergence of neophobic and fussy traits typically occurs at around 2 years of age, greater understanding of the factors associated with food preferences during the preschool years is particularly important in order to develop effective interventions.

Existing studies examining sociodemographic and anthropometric correlates of food preferences and intakes have been particularly inconclusive. The current study will independently explore the relationship between SES, gender, gestational age and weight and children's preferences for multiple foods. Maternal diet, breastfeeding and child's age at the introduction of solid foods are all characteristics of the family dietary environment that have been previously associated with children's food preferences (Borah-Giddens & Falciglia, 1993; Howard et al., 2012; Möller et al., 2013). However findings have been equivocal and have generally focussed on associations with intakes of, or preferences for, fruits and vegetables only. Children's appetitive traits have also been linked to both food intake and liking. While there is a large body of literature on the dietary consequences of neophobia in children, fewer studies have explored the behaviourally overlapping but distinct construct of fussiness. Food fussiness (or pickiness) has been linked with decreased consumption of fruits and vegetables (Galloway et al., 2005; Jacobi et al., 2003) but associations with other foods have received limited attention. Similarly another child appetitive trait, 'enjoyment of food', has been positively related to greater fruit and vegetable consumption (Cooke et al., 2004), but associations with other food groups remain elusive. Additionally, 'food responsiveness' is another appetitive characteristic measured by the Child Eating Behaviour Questionnaire (Wardle, Guthrie, Sanderson, & Rapoport, 2001) that could arguably be expected to relate to children's food preferences but has received no attention to date. Food responsiveness relates to the stimulation of consumption in response to food cues (e.g. smell or sight of palatable food). The present study used a robust design to explore these potential correlates of food preferences in childhood within a large cohort of twin children at 3 years old.

6.2. Study aims

This study will investigate possible factors contributing to the variance in liking for the five food groups; vegetables, fruits, protein, dairy and snacks, established in the previous chapter. As this study is novel in including measures of liking for several food groups, similarities and differences in patterns of associations among these five food groups will also be explored.

6.3. Methods

6.3.1. Sample

The sample for this study was the Gemini cohort at T5 when the twins were a mean age of 3.5 years (n=2686). The characteristics of the cohort have been described in detail in Chapter 4.

6.3.2. Measures

The measures used in this study were collected at three separate time points; T0, T1 and T5. The T0 (baseline) questionnaire was completed when the twins were a mean age of 8.2 months (SD= 2.2, range 4.0-20.3). Data collected at T0 included; gestational age, maternal fruit and vegetable intake, birth weight, socioeconomic status (NS-SEC), feeding method and age at introduction of solid foods. The two booklets that comprised the T0 questionnaire are shown in Appendices 1.5 and 1.6. The T1 Questionnaire was completed by Gemini parents when their twins were a mean age of 15.8 months (SD= 1.2, range 14.0-27.4). Data collected at T1 included; age at introduction of solid foods (repeated from T0) child eating behaviour scales (CEBQ-T) and anthropometric information. The full T1 questionnaire is presented in Appendix 1.7. The T5 Questionnaire was completed by Gemini parents when their twins were on average 3.5 years of age (SD= 0.27, range 2.9 – 5.0). The data collected at T5 included food preferences, the CEBQ food fussiness scale and cross-sectional anthropometric information. The full T5 questionnaire is presented in Appendix 1.8. Finally, cross-sectional weight SDS measurements were calculated using data provided at T5 and also additional measurements provided at intervals throughout the duration of the Gemini study (see Chapter 4 for more detail on the collection of anthropometric data).

6.3.2.1. Food preference items

The development of the food preference scales was described in detail in the previous chapter. Briefly, the T5 questionnaire asked parents to report their child's preference for a large number of individual foods using a 6 point scale. Response options included; 'has never tried', 'dislikes a lot', 'dislikes', 'neither likes nor dislikes', 'likes' and 'likes a lot'. 'Has never tried', was recoded to missing and remaining responses were scored 1, 2, 3, 4, and 5 for these analyses, with higher scores indicating higher liking. Foods that had been tried by at least 75% of the children were then grouped into categories using principal components analysis. This provided 5 distinct food groups (comprising 59 foods in total); 1) vegetables (16 food items), 2) fruits (15 items), 3) protein (9 items), 4) egg and dairy foods (10 items) which will be referred to throughout as 'dairy' and 5) snacks (10). Scale scores were calculated for each child for each of the five food groups by summing all of the available item scores within each subscale and dividing the total value by the number of completed items. Calculation of food group scale scores required complete data for a minimum of 60% of items.

6.3.2.2. Sociodemographic and anthropometric variables

Full details of the sociodemographic and anthropometric variables used in this study are also provided in Chapter 4. Infant sex, gestational age and birth weight were assessed at T0. Information on parent's occupations, used to calculate the National Statistics Socioeconomic Class (NS-SEC) index, was also collected at baseline (T0). NS-SEC was selected as the measure of SES in these analyses because it is now used in all official statistics and surveys relating to health research in the UK (Galobardes, Shaw, Lawlor, Lynch, & Davey Smith, 2006) which permits for comparisons with other studies. NS-SEC also takes into account both the maternal and paternal occupations and has been related to a variety of health outcomes (Bartley, 2004). Three and a half year weight SDS was calculated using data provided in the T5 questionnaire and weight updates given by parents at regular intervals throughout the duration of the Gemini study.

6.3.2.3. Family dietary characteristics

Maternal fruit and vegetable intake ('maternal 5-a-day') and the milk feeding method (breast or formula) used for the first three months of life were measured at baseline (T0). Questions assessing the children's age when they were first introduced to solid foods were initially asked at T0 and repeated at T1. These measures are described in detail in Chapter 4. For the purposes of this study and in order to facilitate the interpretation of results, milk feeding method was dichotomised into 'breastfed' (entirely breastfeeding' or 'mostly breastfeeding with some bottle-feeding') and 'formula-fed' (all other categories including mixed feeding).

6.3.2.4. Child appetitive characteristics

The Child Eating Behaviour Questionnaire (CEBQ) was designed to assess the main eating traits implicated in the development of both under- and overweight (Wardle et al., 2001b). Each subscale has been shown to correlate well with equivalent behavioural measures of these traits (Carnell & Wardle, 2007) and while scores appear to change over time, the scales do show levels of individual continuity comparable with other stable personality traits in children from age 4 to 11 years (Ashcroft et al., 2008).

An adapted version of the CEBQ (the CEBQ-T), designed to be age-appropriate for toddlers, was included in the Gemini questionnaire at T1. The full CEBQ-T comprises six scales in total but only three of these were included in the present study. The three CEBQ-T scales used here did not differ from the original CEBQ, these were; 'food responsiveness' (FR), 'enjoyment of food' (EF) and 'food fussiness' (FF). A full list of the individual items included in the FR, EF and FF scales is presented in Table 6.1. The EF subscale consists of 4 items (Cronbach's α= 0.85, in the current T1 sample) e.g. 'My child enjoys eating'. The FR subscale consists of 4 items (α = 0.75) e.g. 'Given the choice my child would eat most of the time'. The FF subscale consisted of 6 items (α =0.87) e.g. 'My child is difficult to please with meals'. Parents were asked 'How would you describe your twins' eating styles on a typical day?' and all items were scored on a 5-point scale as 'never', 'rarely', 'sometimes', 'often', or 'always'. Mean scores were calculated for each subscale (range: 1–5) with higher scores indicating a greater enjoyment of food, higher food responsiveness and greater food fussiness. In order to calculate subscale scores complete data was required on three out of the four individual items for FR and EF and on four out of six items for FF. The food fussiness scale was measured for a second time at T5, using the same six items and response options (α = 0.90).

Table 6.1: Descriptive statistics for child eating behaviour items at T1 and T5

	Mean	SD	N (%)[a]
T1 Food Responsiveness scale (4 items)	**2.27**	**0.76**	**2558 (95.2)**
My child…			
..is always asking for food	2.29	0.92	2550 (95.0)
..if allowed to, would eat too much	2.07	1.03	2556 (95.2)
..given the choice, would eat most of the time	2.19	1.07	2562 (95.4)
..even when just eaten well, he/she is happy to eat again if offered	2.45	0.94	2539 (94.5)
T1 Enjoyment of Food scale (4 items)	**4.18**	**0.62**	**2562 (95.4)**
My child…			
..loves food	4.18	0.73	2566 (95.5)
..interested in food	4.25	0.71	2566 (95.5)
..looks forward to mealtimes	4.03	0.81	2530 (94.2)
..enjoys eating	4.25	0.69	2560 (95.3)
T1 Food Fussiness scale (6 items)[b]	**2.18**	**0.70**	**2562 (95.4)**
T5 Food Fussiness scale (6 items)[b]	**2.65**	**0.85**	**2686 (100)**
My child…			
..refuses new foods at first			
T1	2.52	0.94	2568 (95.6)
T5	2.96	1.06	2677 (99.7)
..enjoys a wide variety of foods (R)[c]			
T1	1.71	0.81	2560 (95.3)
T5	2.10	0.97	2682 (99.9)
..enjoys tasting new foods (R)[c]			
T1	2.36	0.85	2562 (95.4)
T5	2.77	1.00	2682 (99.9)
..is difficult to please with meals			
T1	2.09	0.88	2561 (95.3)
T5	2.40	1.00	2684 (99.9)
..decides s/he doesn't like food without tasting it			
T1	2.05	0.98	2560 (95.3)
T5	2.82	1.10	2683 (99.9)
..is interested in tasting things s/he hasn't tasted before (R)[c]			
T1	2.37	0.90	2560 (95.3)
T5	2.88	1.02	2684 (99.9)

[a] N refers to number of participants providing data on each item (and as a % of the total samples returning T5).

[b] A paired samples t-test showed a significant increase in FF between T1 and T5 ($t(2561)=-29.23$, $p<.001$).

[c] Items labelled (R) were reversed scored. Higher mean scores on every FF item represent greater fussiness (i.e. higher score on 'enjoys tasting new foods' presented here reflect lower enjoyment)

6.3.3. Statistical analyses

All analyses were performed in SPSS Version 20 for Windows, using complex samples linear regression analyses to take into account the clustering of twins within families (Snijders & Bosker, 2012). Regression analyses permit prediction of an outcome variable from one (univariate regression) or multiple (multiple regression) predictor variables. The β -value represents the gradient of the regression line, and thus the strength of the relationship between a predictor and the outcome variable (Field, 2009). If the β –value is significant, this means the predictor variable significantly predicts the outcome. An alpha level of <0.01 was adopted throughout this study to account for the large sample size and multiple testing. The R^2 indicates the proportion of variance in the outcome variable that is explained by the model. R^2 provides a good measure of the substantive size of the relationship between the predictor and outcome variables (Field, 2009).

Unadjusted linear regression analyses were conducted first to identify significant univariate relationships between each of the independent variables and preferences for each of the five food groups (vegetables, fruit, protein, dairy and snacks). Child appetitive and family dietary characteristics were then each entered into an adjusted linear regression model to investigate whether associations with food preferences remained significant when controlling for sociodemographic and anthropometric factors.

<u>6.3.3.1. Factors associated with food preferences - unadjusted models</u>

The dataset was inspected to ensure that it met the necessary assumptions for linear regression analyses. There are several assumptions that justify the use of linear regression models, these include; normality, linearity, independence of the errors, homoscedasticity and multicollinearity. Linearity requires that the relationship between dependent and independent variables to be linear and can be assessed by examining scatter plots. Independence refers to the fact that the residuals should be uncorrelated and this assumption can be tested with the Durbin–Watson test, which tests for serial correlations in the residuals (between errors). Homoscedasticity requires constant variance of the errors; this means that the residuals at each level of the predictor(s) variable should have the same variance. The assumption of multicollinearity requires that there should be no perfect linear relationship between two or more of the predictors, i.e. that predictor variables should not correlate too highly (e.g. above 0.80) (Field, 2009). These assumptions were not violated in the present study.

Univariate linear regression was used to assess relationships between each variable (child, family, sociodemographic and anthropometric) and preferences for each of the five food groups (vegetables, fruits, protein, dairy and snack). For the child weight variables, exact age at weight measurement was controlled for within the models.

6.3.3.2. Factors associated with food preferences - adjusted models

As sociodemographics and anthropometrics are known to be interrelated with family dietary and child appetitive characteristics; multiple linear regression analyses were performed. Adjusted linear regression models assessed the relationships between family dietary/child appetitive characteristics and preferences for each of the five food groups, while controlling for sociodemographic and anthropometric variables (i.e. sex, gestational age, NS-SEC and concurrent weight).

6.3.3.3. Secondary analyses of food fussiness and food preferences

Food Fussiness was the only familial or child characteristic measured concomitantly with food preferences at T5. It is therefore possible to explore the development of this trait over time and also to compare cross-sectional and longitudinal associations between food fussiness and food preferences. A paired samples t-test was used to assess changes in FF between the two time points and FF was found to be significantly lower at T1 (2.18) compared to T5 (2.65) (t (2561)=-29.23, p<0.001), showing that children's fussiness increased with age. As FF was stronger at T5, associations between this trait and food preferences measured at the same time (T5) were explored using adjusted linear regression models, while controlling for sex, gestational age, NS-SEC and concurrent weight.

6.3.4. Power

Power calculations for multiple regression analyses were calculated using G-Power (version 3.1.7) based on varying sample sizes, for models including 10 predictor variables, at an alpha level of 0.01. A model including the full sample size (n=2686) would be powered at 99% to detect a small R^2 of 0.01; including the smallest available sample for any of the models in these analyses (n=2161) provides 98% power.

6.4. Results

6.4.1. Descriptive statistics

The means and standard deviations for each of the predictor variables and food preference scores are shown in Table 6.2.

Table 6.2: Sample characteristics (n=2686)

	Mean (SD) or **N (%)**	**N**
Sociodemographic and anthropometric variables		
Sex (male)	1332 (49.6%)	2686
Gestational age (in weeks)	36.19 (2.51)	2676
NS-SEC (T0)		2678
Low	394 (14.7%)	
Medium	400 (14.9%)	
High	1884 (70.4%)	
Birth weight SDS	-0.56 (0.93)	2642
3.5 year weight SDS	0.05 (1.00)	2379
Age at 3.5 year weight (years)	3.79 (0.24)	2379
Family dietary characteristics		
Feeding method (breast)	990 (36.9%)	2686
Age at solid food introduction (months)	4.95 (1.06)	2678
Maternal fruit and vegetable intake (portions per day) (T0)	3.72 (1.95)	2664
Child appetitive characteristics		
Enjoyment of Food (T1)	4.12 (0.62)	2562
Food responsiveness (T1)	2.25 (0.76)	2558
Food Fussiness (T1)	2.18 (0.70)	2562
Food Fussiness (T5)	2.65 (0.85)	2686
Food preference scales[a]		
Vegetables	3.47 (0.62)	2598
Fruits	3.91 (0.68)	2598
Protein	3.85 (0.59)	2542
Dairy	3.76 (0.59)	2603
Snacks	4.42 (0.41)	2674

[a] Preferences scored 1-5 at T5 (dislikes a lot, dislikes, neither likes nor dislikes, likes, likes a lot), maximum score of 5.

6.4.2. Associations between sociodemographic and anthropometric variables and food preferences

The results of the unadjusted linear regression models exploring the associations between sociodemographic and anthropometric variables and food preferences are shown in Table 6.3.

6.4.2.1. Gender

The only significant relationships between children's gender and food preferences were found for fruit. Boys were found to have lower preference for fruit than girls (β= -0.118 ± 0.031; *p<0.001*). No significant gender differences were found for any of the other food group preferences.

6.4.2.2. Gestational age

Gestational age was also only found to significantly relate to liking of fruit. A higher gestational age predicted increased liking of fruit (β=0.031 ± 0.007; *p*<0.001). No significant associations were found for gestational age and preferences for any of the remaining four food groups.

6.4.2.3. Socioeconomic status

The only significant relationship between SES (NS-SEC) and food preferences was for snack foods, where higher SES was associated with increased liking (β=0.047 ± 0.016; *p*=0.003).

6.4.2.4. Weight

There were no significant associations between children's birth weight and their food preferences. However weight was found to relate cross-sectionally with liking of fruit, with higher weight SDS at 3.5 years associated with increased liking at this age (β=0.051 ± 0.016; *p*=0.002). Concurrent weight was not significantly associated with any other food preferences.

6.4.3. Associations between family dietary characteristics and food preferences

The results of the unadjusted linear regression models exploring the associations between maternal and family characteristics and food preferences are also shown in Table 6.3**.** The results of the adjusted linear regression models exploring associations between maternal and family characteristics and food preferences, while controlling for sociodemographic and anthropometric variables are shown in Table 6.4.

6.4.3.1. Milk feeding method

A significant association was found between milk feeding method and liking for all food groups except for vegetables. Breastfed infants scored significantly higher for fruit liking (β= 0.136 ± 0.035; p<0.001), protein liking (β= 0.092 ± 0.030; p=0.002), dairy liking (β= 0.092 ± 0.030; p=0.002) and snack food liking (β= 0.063 ± 0.021; p=0.003) than did formula-fed infants. All associations remained significant in the adjusted models with the exception of protein, where the alpha level failed to reach p<0.01 after adjusting for sex, gestational age, SES and concurrent weight.

6.4.3.2. Timing of solid food introduction

The age at which children first started eating solid foods was not significantly associated with liking for any of the food groups with the exception of vegetables. A relationship between earlier introduction to solids and higher liking for vegetables was significant in the unadjusted model (β= -0.047 ± 0.015; p=0.001) and remained so after adjusting for sociodemographic and anthropometric covariates.

6.4.3.3. Maternal fruit and vegetable intake

Higher maternal fruit and vegetable intake was associated with increased liking for vegetables (β= 0.040 ± 0.008; p<0.001), fruits (β= 0.052 ± 0.009; p<0.001), protein (β= 0.032 ± 0.008; p<0.001) and dairy foods (β=0.022 ± 0.008; p=0.008) but not snack foods. All of these associations remained significant in the adjusted models.

6.4.4. Associations between child appetitive characteristics and food preferences

The results of the unadjusted linear regression models exploring the associations between child appetitive characteristics and food preferences are shown in Table 6.3. The results of the adjusted linear regression models exploring associations between child characteristics and food preferences, while controlling for sociodemographic and anthropometric variables, are shown in Table 6.4.

6.4.4.1. Enjoyment of food

Higher ratings of ‘enjoyment of food’ were associated with increased liking for each of the food groups; vegetables (β=0.187 ± 0.025; p<0.001), fruits (β=0.184 ± 0.028;

$p<0.001$), protein (β= 0.130 ± 0.024; $p<0.001$), dairy (β=0.071 ± 0.025; $p=0.004$), apart from snacks where the association failed to reach significance at the $p<0.01$ level (β= 0.034 ± 0.016; $p=0.037$). The same pattern was observed following adjustment for sociodemographic and anthropometric variables.

6.4.4.2. Food responsiveness

The only significant association between 'food responsiveness' and food preferences was for snack foods (β=0.048 ± 0.014; $p<0.001$). This association between higher food responsiveness and increased liking for snacks remained following adjustment for sex, gestational age, NS-SEC and concurrent weight.

6.4.4.3. Food fussiness

Highly significant associations between children's food fussiness (measured at T1) and preferences for all food groups with the exception of snack foods were observed. Fussier children displayed lower liking for vegetables (β= -0.259 ± 0.023; $p<0.001$), fruits (β= -0.257 ± 0.024; $p<0.001$), protein foods (β= -0.157 ± 0.023; $p<0.001$) and dairy foods (β= -0.119 ± 0.023; $p<0.001$) with all associations remaining significant after adjusting for sociodemographic and anthropometric variables. No significant relationship was found between food fussiness and snack food preference in either model. FF was the predictor explaining the largest amount of variance in liking for vegetables (9%; R^2=0.085), fruit (7%; R^2=0.067), protein (4%; R^2=0.035) and dairy (2%; R^2=0.019) in the adjusted models.

Table 6.3: Factors associated with food preference – unadjusted models

	Vegetables (n=2335-2639)			Fruit (n=2306-2598)			Protein (n=2243-2542)			Dairy (n=2311-2603)			Snacks (n=2370-2674)		
	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2
Sociodemographic and anthropometric variables															
Sex (male)	-.024 (.028)	.389	<.001	**-.118 (.031)**	**<.001**	**.007**	-.065 (.027)	.016	.003	-.049 (.027)	.065	.002	-.009 (.018)	.611	<.001
Gestational age (weeks)	.004 (.007)	.515	<.001	**.031 (.007)**	**<.001**	**.013**	.002 (.006)	.783	<.001	-.001 (.006)	.906	<.001	.010 (.004)	.018	.004
NS-SEC [a] (T0)	-.014 (.023)	.528	<.001	.032 (.025)	.197	.001	.043 (.021)	.036	.003	-.011 (.022)	.610	<.001	**.047 (.016)**	**.003**	**.005**
Birth weight SDS	.003 (.015)	.855	<.001	.001 (.016)	.968	<.001	-.010 (.015)	.509	<.001	-.002 (.015)	.885	<.001	-.003 (.010)	.787	<.001
3.5 year weight SDS [b]	.013 (.016)	.395	<.001	**.051 (.016)**	**.002**	**.005**	.011 (.016)	.485	<.001	.018 (.014)	.191	.001	.012 (.010)	.262	.001
Family dietary characteristics															
Feeding method (breast)	.046 (.032)	.150	.001	**.136 (.035)**	**<.001**	**.009**	**.092 (.030)**	**.002**	**.006**	**.092 (.030)**	**.002**	**.006**	**.063 (.021)**	**.003**	**.005**
Age at solid food introduction (months)	**-.047 (.015)**	**.001**	**.007**	-.012 (.016)	.453	<.001	.012 (.012)	.313	.001	.000 (.015)	.980	<.001	.000 (.009)	.972	<.001
Maternal fruit and vegetable intake (T0)	**.040 (.008)**	**<.001**	**.016**	**.052 (.009)**	**<.001**	**.022**	**.032 (.008)**	**<.001**	.012	**.022 (.008)**	**.008**	**.005**	-.004 (.006)	.465	<.001
Child appetitive characteristics															
Enjoyment of Food (T1)	**.187 (.025)**	**<.001**	**.034**	**.184 (.028)**	**<.001**	**.026**	**.130 (.024)**	**<.001**	**.019**	**.071 (.025)**	**.004**	**.005**	.034 (.016)	.037	.003
Food Responsiveness (T1)	.016 (.022)	.445	.000	.051 (.023)	.025	.003	.035 (.019)	.058	.002	.021 (.020)	.315	<.001	**.048 (.014)**	**<.001**	**.008**
Food Fussiness (T1)	**-.259 (.023)**	**<.001**	**.085**	**-.257 (.024)**	**<.001**	**.067**	**-.157 (.023)**	**<.001**	**.035**	**-.119 (.023)**	**<.001**	**.019**	-.011 (.015)	.461	<.001
Food Fussiness (T5)	**-.430 (.015)**	**<.001**	**.342**	**-.357 (.019)**	**<.001**	**.190**	**-.287 (.018)**	**<.001**	**.168**	**-.220 (.016)**	**<.001**	**.099**	**-.045 (.012)**	**<.001**	**.009**

[a] NS-SEC; National Statistics Socioeconomic Class
[b] Model adjusted for age at weight measurement
Significant values (at an alpha level of p<0.01) are **bolded**.

Table 6.4: Factors associated with food preference – adjusted models*

	Vegetables (n=2249-2329)			Fruit (n=2220-2300)			Protein (n=2161-2237)			Dairy (n=2222-2305)			Snacks (n=2276-2364)		
	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2	Beta (SE)	p value	R^2
Family dietary characteristics															
Feeding method (breast)	.061 (.034)	.070	.004	**.136 (.036)**	**<.001**	**.040**	.080 (.032)	.013	.011	**.101 (.032)**	**.002**	**.010**	**.063 (.022)**	**.004**	**.017**
Age at solid food introduction	**-.044 (.016)**	**.009**	**.007**	-.001 (.018)	.955	.031	.013 (.014)	.347	.007	-.005 (.015)	.725	.004	.007 (.010)	.499	.012
Maternal fruit and vegetable intake (T0)	**.036 (.009)**	**<.001**	**.014**	**.048 (.009)**	**<.001**	**.049**	**.031 (.008)**	**<.001**	**.017**	**.023 (.009)**	**.008**	**.009**	-.006 (.006)	.314	.013
Child appetitive characteristics															
Enjoyment of Food (T1)	**.206 (.027)**	**<.001**	**.042**	**.202 (.030)**	**<.001**	**.062**	**.146 (.026)**	**<.001**	**.028**	**.081 (.026)**	**.002**	**.011**	.040 (.017)	.019	.016
Food Responsiveness (T1)	.032 (.024)	.180	.003	.054 (.024)	.027	.034	.047 (.021)	.026	.010	.035 (.022)	.110	.006	**.052 (.014)**	**<.001**	**.021**
Food Fussiness (T1)	**-.263 (.023)**	**<.001**	**.090**	**-.262 (.025)**	**<.001**	**.100**	**-.163 (.025)**	**<.001**	**.043**	**-.106 (.024)**	**<.001**	**.020**	-.016 (.016)	.310	.013
Food Fussiness (T5)	**-.429 (.016)**	**<.001**	**.340**	**-.353 (.020)**	**<.001**	**.212**	**-.291 (.020)**	**<.001**	**.175**	**-.211 (.018)**	**<.001**	**.094**	**-.044 (.013)**	**.001**	**.020**

[a] Models adjusted for sex, gestational age, NS-SEC (National Statistics Socioeconomic Class) and concurrent weight (weight at 3.5 years)
Significant values (at an alpha level of p<0.01) are **bolded**.

6.4.5. Age-related differences in food fussiness and its relationship with food preferences

Cross-sectional univariate analyses of the relationship between food fussiness measured at T5 and food preferences (which were also measured at T5) are shown in Table 6.3. Strong associations were found between increased fussiness and lower liking of vegetables (β= -0.430 ± 0.015; p<0.001), fruits (β= -0.357 ± 0.019; p<0.001), protein foods (β= -0.287 ± 0.018; p<0.001) and dairy foods (β= -0.220 ± 0.016; p<0.001) and these associations remained after adjustment for sociodemographic and anthropometric variables (see Table 6.4). Unlike T1 food fussiness scores, fussiness measured at T5 was also found to be associated with decreased liking of snacks (β= -0.045 ± 0.012; p<0.001), although this relationship did appear weaker compared to the other four food groups. The adjusted models including FF measured at T5 explained as much as 34% of the variance in vegetable liking (R^2=0.340), 19% of the variance in liking for fruit liking (R^2=0.190) and 17% of the variance in liking of protein (R^2=0.168) measured at this age. In comparison 10% of the variance in dairy food liking (R^2=0.099) and only 1% of the variance in liking of snack foods (R^2=0.009) was explained by FF at T5.

6.5. Discussion

6.5.1. Summary of findings

This study identified multiple factors associated with food preferences in infants and young children. The factors associated with food preferences varied between food groups, as did the strength of the associations. Characteristics of the children themselves were consistently associated with liking for most food groups, while the pattern of associations between familial characteristics and food preferences was more varied. Few significant associations were found with sociodemographic and anthropometric factors.

As predicted, higher maternal fruit and vegetable intake was associated with increased liking for vegetables and fruits. Perhaps unexpectedly, similar associations were seen for protein and dairy foods. The relationship between maternal fruit and vegetable intake and children's liking for these foods is consistent with previous research (Cooke et al., 2004; Howard et al., 2012; McGowan et al., 2012; Pearson et al., 2009) and is likely to be the result of parental modelling together with increased exposure to these foods in the home from an early age. It is also likely that the association between maternal intake and children’s liking for fruits and vegetables is the result of a heritable component to preference (Breen et al., 2006). It is possible that maternal fruit and vegetable intake is indicative of a varied maternal diet more generally, which could account for the association with an increased liking for protein and dairy foods observed in this study. Greater maternal dietary variety has been associated with decreased fussiness in children (Galloway et al., 2003) and it has been suggested that early exposure to variety is associated with increased food acceptance in infancy and childhood (Mennella et al., 2008).

Breastfed children showed increased preference for all the food groups excluding vegetables and with the exception of protein foods, these associations remained after adjustment for sociodemographic and anthropometric variables. The beneficial effect of breastfeeding on later food acceptance has been reported previously (Sullivan & Birch, 1994). However, the lack of an association between breastfeeding and vegetable liking contrasts with research reporting higher vegetable intake in breastfed children at two to six years of age (Cooke et al., 2004; Nicklaus et al., 2005). There is some evidence to suggest that breastfeeding may only confer an advantage on acceptance of foods if mothers have regularly consumed these (or similar tasting) foods during lactation (Forestell & Mennella, 2007). This might help to explain why maternal fruit and vegetable intake, but not breastfeeding, was associated with liking for vegetables. Nonetheless, breastfeeding was positively associated with preferences for all of the other food groups.

Previous research has suggested the key mechanism driving increased taste acceptance in breastfed infants is exposure to a variety of tastes; with the multiple flavours from the maternal diet transmitted through breast milk offering a varied oral sensory experience to infants that continues to have an effect into childhood. Studies have found a positive impact of breastfeeding on infant’s acceptance of umami (savoury) tastes and unusual novel flavours (caraway) (Hausner, Nicklaus, Issanchou, Molgaard, & Moller, 2010; Schwartz et al., 2012). It is possible that the increased flavour acceptance observed in breastfed children results in higher liking for a wide range of foods, but that this advantage is not sufficient to override the common rejection in early childhood of intrinsically less palatable foods, such as vegetables.

The finding that children who started solid foods earlier displayed an increased preference for vegetables at 3 years was unexpected and very interesting. A recent study in Australia reported a contrasting finding of increased non-core food preferences in children introduced to solids earlier (Howard et al., 2012). Other studies have found increased consumption of snack foods in children introduced to solids before four months (Grummer-Strawn et al., 2008), but this is a full two months earlier than current UK guidelines recommend. In contrast, the average age children first received solids in the Gemini sample was just under five months, and only 7% of Gemini mothers introduced solids prior to four months. In the Australian sample the average age solids were first introduced was over five months (23 ± 5 weeks) (Howard et al., 2012), so it is unlikely that the disparity in the findings from these two studies arises from differences in what constitutes ‘early weaning’. Alternatively, it is possible these contrasting findings result from differences in the types of foods consumed by the two samples during early complimentary feeding. Previous research using Gemini data has shown that the first solid foods eaten were core foods (including fruit, vegetables, starches, meat and dairy) and core foods were consumed on average four months earlier than non-core foods (e.g. snacks, fried potatoes and processed meats) in this sample (Schrempft, van Jaarsveld, Fisher, & Wardle, 2013). Perhaps earlier exposure to vegetables specifically is driving this association in the present study.

The finding of increased vegetable liking among children introduced to solid foods earlier suggests that the current recommendation to delay complementary feeding until six months may have negative consequences for children’s future food preferences. The relationship between vegetable liking and age at introduction to solids provides support for the concept of a sensitive period for flavour acceptance with some previous research indicating heightened plasticity in infants’ flavour acceptance prior to six or seven months (Harris et al., 1990; Mennella & Beauchamp, 1996a; Mennella et al., 2011; Trabulsi & Mennella, 2012). Another study has also provided limited evidence for a relationship between earlier vegetable introduction and later intake, although the association did not remain significant following adjustment for covariates (e.g. parental consumption and neophobia) (Cooke et al., 2004).

The increased liking for vegetables observed in children who consumed solids at a younger age may not simply result from exposure to the flavours of these commonly rejected foods during a key period in children’s development. Other food properties, such as texture, also affect preference and earlier introduction to lumpy foods has been shown to relate to later food acceptance, including vegetable intake (Coulthard et al., 2009). Children who start eating solids at a younger age are likely to try a wider variety of foods and textures earlier, and these combined early experiences may confer an advantage on later preference.

The variable most strongly associated with children’s food preferences was food fussiness. Food fussiness significantly increased from 15 months to age 3 years, which is consistent with the general consensus that neophobic and picky traits begin to increase during the second year of life and do not start declining until after the age of 5 (Cashdan, 1994). A previous study exploring the longitudinal stability of eating behaviour traits in children reported that food fussiness decreased from age 4 to age 10 (Ashcroft, Semmler, Carnell, van Jaarsveld, & Wardle, 2008). Fussiness measured at 15 months (T1) was strongly and negatively associated with preferences for all food groups, except snacks. These relationships were even stronger when fussiness was measured concomitantly with food preferences at three years, with fussiness explaining as much as a third of the variance in vegetable liking.

There were no associations between food fussiness measured at 15 months and snack food liking in this sample. Additionally, the relationship between fussiness measured at three years and concomitant snack liking was weaker in comparison to the other food groups. A similar finding has been reported in Australian toddlers, where neophobia was found to associate with decreased liking for fruit and vegetables but not snack foods (Howard et al., 2012). Elsewhere, there is evidence to suggest fussy children may consume more sweetened foods (Carruth et al., 2004). Its seems the innate liking for sweetness is not reduced in fussy children and consequently there could be a risk that, through a narrowing of dietary variety and rejection of nutrient-dense foods, fussy children may rely on an overconsumption of energy-dense, highly palatable foods. This may ultimately put fussy children at risk of excessive weight gain, although existing prospective studies of fussy eating and weight have either failed to find an association (Wardle, Guthrie, Sanderson, & Rapoport, 2001) or have reported the opposite effect (Dubois et al., 2007). The literature would benefit from further investigations with large prospective cohorts, using reliable measures of fussy eating to investigate long-term associations with weight.

The apparently stronger associations observed between food preferences and fussiness measured at 3 years compared to fussiness measured at 15 months may reflect the increase in children’s fussiness over this period. However these findings also likely result from the cross-sectional versus longitudinal nature of the predictor variable. Associations between variables measured at the same point in time are likely to be stronger than associations between factors measured in infancy and those measured several years later. It is therefore likely that the associations between the child appetitive characteristics and maternal fruit vegetable intake measured in this study and liking for each of the food groups would have been stronger if measured cross-sectionally as opposed to longitudinally.

Enjoyment of food was also found to be highly predictive of liking for all foods except snacks. Children who enjoy food more, displayed a higher liking for all foods, including fruits and vegetables. This finding supports previous research linking greater enjoyment of food with higher consumption of fruit and vegetables (Cooke et al., 2004). Interestingly, the relationship between enjoyment of food and preference for snacks appears weaker and was not significant in either the unadjusted or adjusted models, while food responsiveness was *only* associated with snack preference. It seems food responsiveness singularly relates to increased liking for ‘unhealthy’ energy-dense foods.

Contrary to previous research which has suggested an association between adiposity and an increased liking for sweet and fatty foods (Fisher & Birch, 1995; Lanfer et al., 2012; Ricketts, 1997), weight was unrelated to snack food liking in this study. This is not the first study to find liking for fatty or sugary foods was unrelated to children’s weight or adiposity (Fieldstone et al., 1997; Hill et al., 2009). In the current analyses, the only relationship between concurrent weight and food preferences was a positive association with liking for fruit. This again contrasts with a previous study which reported an association between greater liking for both fruits and vegetables and *lower* weight in ten to eleven year olds (Lakkakula et al., 2008). It is possible that the age differences in these two samples partially explains these contrasting findings but longitudinal studies are needed to further understanding of the relationship between children’s food liking and weight.

Similarly, few associations were found between sociodemographic variables and liking for the five food groups. Female sex and older gestational age were positively related to liking for fruit but not for any of the other four food groups The finding of a higher liking for fruit among girls in this study replicates findings of earlier research (Cooke & Wardle, 2005; Diehl, 1999; Lien et al., 2001; Reynolds et al., 1999). However, unlike previous studies no gender differences were found for vegetable, snack or protein liking (Cooke & Wardle, 2005; McFarlane & Pliner, 1997). Higher SES was found to relate to increased liking for snack foods at 3 years. Although this relationship is unexpected, the association is very small, explaining less than 0.5% of the variance in this trait, and may simply be a statistical anomaly.

6.5.2. Limitations

This study has several limitations require that acknowledgement. Despite the prospective study design it is not possible to draw conclusions about the direction of many of the relationships identified or to infer causation. Additionally, maternal fruit and vegetable intake and family SES were assessed at baseline, when the children were on average eight months old, so associations between food preferences at T5 and these variables may have been underestimated compared with the contemporaneously measured factors. Associations between CEBQ scales measured at T1 (when children were 15 months old) and preferences at 3 years may have been similarly compromised, an assertion that is supported by the stronger cross-sectional associations observed between fussiness and preferences measured at the same age.

All information was reported by parents, which as a result of social desirability bias, might have resulted in an over-estimation of maternal fruit and vegetable intake. Measures of the timing of solid food introduction and feeding method were also self-report and collected retrospectively which may have led to memory errors and bias. However, collecting solid food introduction data at two time points did mean that where possible parents reported their feeding habits relatively soon after the time they occurred. Furthermore previous research has demonstrated retrospective measures of infant feeding practices, recalled 18 months postpartum, to be reasonably accurate (Launer et al., 1992).

The CEBQ scales of food responsiveness, enjoyment of food and food fussiness used in this study are parent-report measures of children's eating appetitive characteristics. These scales have been shown to have a robust factor structure and good internal reliability (Wardle, Guthrie, Sanderson, & Rapoport, 2001). The food responsiveness and enjoyment of food scales have also been successfully validated against behavioural measures in four to five year old children (Carnell & Wardle, 2007). However, while the food fussiness subscale also showed good internal reliability it has not been externally validated. Moreover, all scales would benefit from external validation in a toddler sample to confirm their use is appropriate in a younger age group.

The data in this study comes exclusively from twins and it is well-documented that the weight trajectories of twins differ from singletons (Grumbach et al., 1986; Ong & Loos, 2006; van Dommelen, de Gunst, van der Vaart, van Buuren, & Boomsma, 2008). Replication of the analyses examining associations between weight and food preferences in singletons would add credibility to these findings. In addition, while birth weights were measured by health professionals, weights at 3.5 years were parent-reported and therefore likely to be less reliable. However, all Gemini parents were provided with free calibrated weighing scales and detailed operating instructions and there is evidence from previous cohort studies that parent measures of their children's weight correlate highly with researcher measures (Wardle, Carnell, Haworth, & Plomin, 2008).

The NS-SEC measure of SES was derived using the simplified method of classifying occupation which does not take account of employment status or organisation size. Although this method correctly allocates 83% of cases compared with the full method, it does slightly overestimate SES (Office for National Statistics, 2005). However this would only be a limitation for the current study if overestimation did not occur systematically, in which case an underestimation of the associations between SES and preferences may have resulted.

6.5.3. Conclusion

This study identified a number of key factors associated with preferences for both 'healthy' and 'unhealthy' foods in early childhood and differential patterns of associations have been observed among the different food groups. The strongest associations to emerge from these analyses were between child appetitive characteristics, specifically food fussiness, and liking for fruits and vegetables in particular. These findings indicate that aspects of the early family feeding environment, as well as children's own appetitive characteristics, are related to a child's unique patterns of food preferences.

CHAPTER 7 . STUDY 3: GENETIC AND ENVIRONMENTAL INFLUENCES ON FOOD PREFERENCES IN INFANCY AND EARLY CHILDHOOD[14]

7.1. Background

The literature review on the relative influences of genes and environment on the development of food preferences in Chapter 1 cited extensive evidence of environmental influences on these traits. In contrast, investigation of genetic influences on food preferences is limited. Very few family and twin studies have systematically investigated the heritability of food preferences, and those that have were limited by small sample sizes.

Parental and health professional's views on the aetiology of children's food preferences show strong disparity. The prevailing message from health professionals and organisations, suggests giving children healthy foods in early life – and avoiding junk foods – results in enduring healthy food preferences (National Institute for Health & Clinical Excellence, 2006). Thus the home food environment, a construct that encompasses both the physical availability of food and parental practices within the home, is seen as a key influence on children's preferences and diets. Contrastingly, parents themselves often focus on the characteristics of their child. Many parents describe regular struggles to get a 'picky' child to eat healthily and report feeling that their children's preferences are somehow 'hard-wired' and difficult to modify. In families with more than one child, parents often remark on the differences between siblings, despite having treated them the same (e.g. 'my first was fussy from the start but my second is easy'; 'he won't even have vegetables on the plate and she loves them') (Russell & Worsley, 2013; Webber, Cooke, & Wardle, 2010). These individual differences suggest that there is a genetic component to food preferences and that a shared home food environment does not wholly create these preferences.

Evidence for genetic influence on taste preference comes from the discovery of genes related to sensitivity to, and preferences for, bitter, sweet and umami, and more recently, fat (Adler et al., 2000; Bachmanov, Reed, Li, & Beauchamp, 2002; Chandrashekar et al., 2000; Garcia-Bailo, Toguri, Eny, & El-Sohemy, 2009; Huang et al., 2006; Laugerette et al., 2006; Li et al., 2002). However, genetic influences on likes

[14] A version of this chapter has been submitted for publication and is currently under review: Fildes A, van Jaarsveld CHM, Llewellyn C H, Fisher A, Cooke L. & Wardle J. (2013). Nature and nurture in children's food preferences. (under review)

and dislikes for actual foods rather than tastes are under-researched and to date it has not been possible to estimate the magnitude of genetic influences on food preferences through the identification of related genes. More direct evidence of a genetic contribution to food preferences comes from examinations of the extent of variation in preferences among family members with genetic relatedness. The observed similarity between parental and child preferences (Borah-Giddens & Falciglia, 1993; Howard et al., 2012) has been viewed as support for environmental effects, although studies of this kind cannot distinguish genetic from environmental factors. The twin design makes it possible to decompose genetic and environmental influences by comparing the degree of resemblance of MZ twin pairs (who share 100% of their genes) and DZ pairs (who share 50% of their genes). Several twin studies have indicated modest genetic effects on preferences for some individual foods, including; broccoli, cottage cheese and chicken (Falciglia & Norton, 1994), and green beans, bacon and strawberries (Krondl et al., 1983).

To achieve robust estimates, large sample sizes are needed but most of the existing twin studies investigating food preferences have had small samples (e.g. 35 pairs) and have been unable to quantify the shared environment effect (Falciglia & Norton, 1994; Krondl et al., 1983). The largest study to date analysed data from 214 twin pairs from the Twins Early Development Study (TEDS) (Breen et al, 2006). Genetic and environmental contributions to preferences were investigated for four food groups and estimates of shared environment effects ranged from 12 to 64% while estimates of genetic effects ranged from 20-78%; but even with this sample size, the estimates had large confidence intervals and the authors acknowledged the need for further studies.

Developmental change in heritability estimates over time is a well-documented phenomenon, and has been reported for multiple behavioural phenotypes including; externalising behaviours, anxiety symptoms, depressive symptoms, IQ, social attitudes, physical activity and eating attitudes (Bergen, Gardner, & Kendler, 2007; Klump, McGue, & Iacono, 2000; Simonen, Levalahti, Kaprio, Videman, & Battie, 2004). However, this has never been investigated in the context of food preferences. Understanding differences in the relative influence of genes and the environment on behavioural phenotypes at different stages in the lifespan is key for informing attempts at trait modification. If environmental influences are stronger at one particular time point, then systematic (population level) interventions targeting this age group have the greatest chance of success. Conversely if genetic influences are dominating, then interventions that are focussed at the individual level may be more appropriate.

The goal of the present study is to investigate the contribution of genes and environment to children's food preferences in infancy and early childhood, while exploring developmental changes in these contributions over time, using data from over 1300 pairs of young twins.

7.2. Study aims

This study aims to (i) quantify the relative influences of genes and the environment on preferences for major food groups at 15 months (T1) and 3 years of age (T5) and (ii) to examine the longitudinal genetic associations between food preferences at these two time points in early childhood.

7.3. Methods

7.3.1. Sample

The sample for this study was the Gemini cohort at T1 (n=3854) and T5 (n=2686). The characteristics of the cohort at these two time points have been described in detail in Chapter 4. The univariate heritability analyses were conducted using the samples at T1 and T5 separately. The longitudinal heritability analyses were conducted using the T1 and T5 data combined (n=2655).

7.3.2. Measures

The development of the T1 and T5 food preference scales used in this study has already been described in detail in the preceding chapters of this thesis. To summarise, preference scores were calculated for five food groups; vegetables, fruit, protein, dairy and snacks, at two time points; T1, when the children were a mean age of 15 months and T5, when the children were 3.5 years. The questions used to measure food preferences at 15 months (T1) required parents to rate their twin's preferences for categories of foods (e.g. 'vegetables' or 'sweet snacks'). These food preference questionnaire (FPQ) items measured at T1 were subsequently grouped into categories reflecting the food group factors that emerged from a principal components analysis (PCA) of the T5 FPQ. The T5 FPQ included a large number of individual foods and those tried by 75% of the children were included in the PCA. Scale scores were calculated for each child for each of the five food groups at each time point. The five food group scores required complete data for a minimum of 50% of items at T1, and

60% of items at T5. For a more detailed description of the food preference measures used in this study please see Chapter 5.

7.3.3. Statistical analyses

7.3.3.1. Descriptive statistics

The descriptive statistics of Food Preference Questionnaire (FPQ) scales at both T1 and T5 are described in detail in Chapter 5. Independent samples t-tests were used to test for differences by zygosity for each of the FPQ scales. As described previously, non-parametric equivalents were used as well, but results are only reported for the parametric tests as the results were similar. An alpha level of 0.01 was selected for significance to minimise the risk of a Type 1 error resulting from the large sample and multiple tests. These analyses were conducted in SPSS version 20 for Windows.

7.3.3.2. Univariate heritability analyses

The heritability of food preference scale scores in each age group were investigated using two methods; intraclass correlations and standard ACE model-fitting analyses. All analyses for heritability were conducted on scores that had been residualised for age- and sex-effects using a regression procedure. Standardised age- and sex-adjusted scores were calculated because the age of twins is exactly correlated within each pair, as is sex within same-sex pairs, and variation within age and sex at the time of testing could contribute to the correlation between twins, potentially inflating the shared environment effect (Mcgue & Bouchard, 1984). Intraclass correlations were calculated for each zygosity group for the residualised preference scores of the 84 individual foods measured at T5.

7.3.3.2.1. Intraclass correlations

Within-pair intraclass correlations were calculated for the residual food preference scores for MZ and DZ groups. A greater difference between the MZ and DZ correlations suggests higher heritability.

7.3.3.2.2. Standard ACE model-fitting analyses

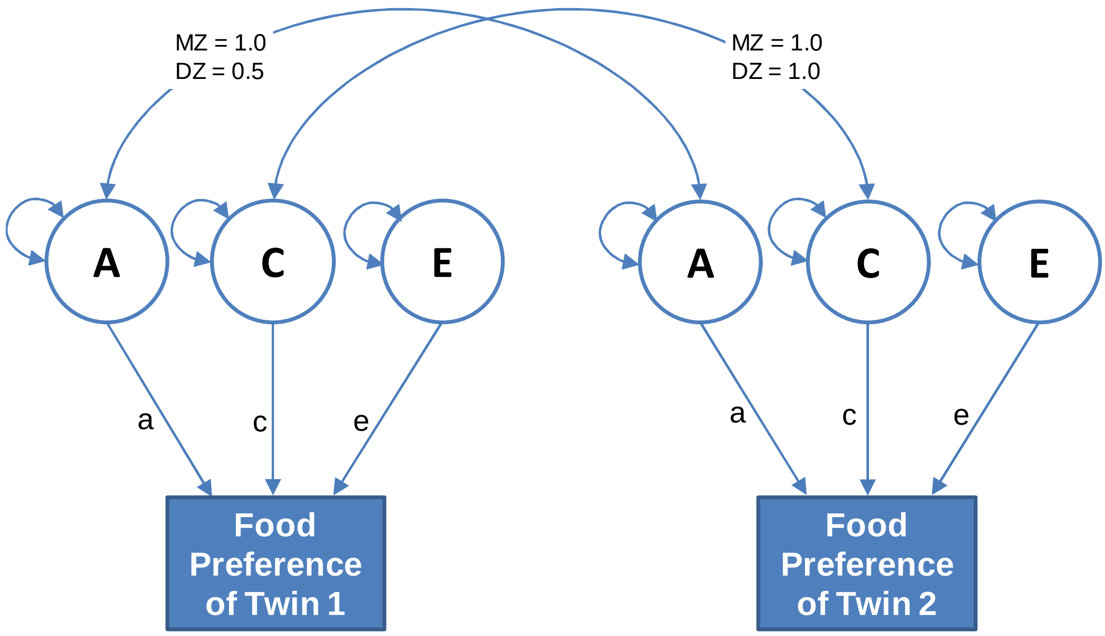
Model-fitting techniques using the Mx structural equation modelling software (version 32; Virginia Commonwealth University, Richmond, VA) (M. C. Neale et al., 2003) were used to apportion the phenotypic variance to genetic and environmental components of variance. These techniques provide more reliable estimates of genetic and environmental effect sizes than intraclass correlations because this method uses covariance between twin pairs rather than correlations. In addition this technique utilises the variance in the scores of the whole sample rather than simply the correlations between the twin pairs. Structural equation modelling techniques also test the goodness of fit of the full model (ACE) versus alternative models, and provide 95% confidence intervals for the parameter estimates. Using the Mx software, standard ACE model-fitting analyses were run for each of the FPQ scales to estimate the additive genetic (A), shared environment (C), and non-shared environment (E) effects (M. C. Neale et al., 2003). The full ACE model dissects the phenotypic variance into these three components, with measurement error included in the non-shared environment (e^2) estimate. The Mx programme fits the full ACE model and three sub-models to the data.

Model fit is assessed on two criteria: the Likelihood Ratio Test (LRT) assessed using chi-square (χ^2) and Akaike Information Criterion (AIC) (Akaike, 1987). The three sub-models that are compared with the full ACE model include: the CE model, which drops the A parameter and assesses the variance explained by C and E only; the AE model which drops C and assesses the variance explained by A and E only; and, the E model, which drops both A and C and assesses the variance explained by E only. Goodness of fit is indicated by a low $\Delta\chi^2$, as this suggests the model is not significantly different from the data. For the LRT, a greater number of parameters improve the goodness of fit of the model, irrespective of the number of parameters that actually explain variance in the data. Whereas AIC rewards goodness of fit while penalizing models for the number of parameters estimated, favouring the model that explains the greatest proportion of the observed data with the fewest parameters. AIC aids selection of the best-fitting model, with lower AIC values indicating better fit (Burnham & Anderson, 2002).

Figure 7.1 shows a path diagram of the ACE model-fitting analyses. The rectangular boxes represent measured phenotypes for each twin (e.g. food preference). The circles represent latent influences on the measured phenotype for each twin, including; additive genetic effects (A), shared environmental effects (C) and non-shared environmental effects (E). The straight, single-headed straight arrows show the causal paths (i.e. the phenotype for each twin results from the collective influence of ACE); the curved, double-headed arrows show the covariance paths (e.g. correlations between the two twins for each factor). The genetic effect (A) is perfectly correlated between MZ pairs so the correlation is fixed at 1.0 for MZs, but as DZs only share on average 50%

of their segregating genes, the correlation is set at 0.5 for DZs. The coefficient for the shared environment (C) is fixed at 1.0 for both MZs and DZs as this is assumed to be the same regardless of zygosity. Unique environmental factors are responsible for phenotypic differences between twins so E is uncorrelated between twin pairs. The proportion of variance in the measured phenotype explained by the latent factors may be estimated by squaring the path coefficients (i.e. a^2, c^2, e^2; the three components together add up to 100%).

Figure 7.1: Path diagram of the ACE model-fitting analyses



<u>7.3.3.3. Longitudinal bivariate heritability analyses</u>

The standard ACE univariate model can be extended to include the same phenotype measured at multiple time points (or multiple phenotypes). Multivariate genetic model-fitting enables testing of whether common genetic, common shared environmental or common unique environmental influences contribute to the same trait at different time points (or to multiple correlated phenotypes at a single time point). Multivariate models also allow us to quantify the relative common influences of genes and the environment to longitudinal (or cross-sectional) phenotypic correlations – i.e. does the correlation between liking for vegetables at 15 months and 3 years mainly result from common genes that influence preference at both ages, or common environments that encourage this preference at both time points?

While in univariate heritability analyses the focus is on within-pair within-trait covariation (i.e. how is Twin 1's preference for vegetables associated with Twin 2's preference for vegetables), multivariate heritability analyses focus on within-pair cross-covariation between different time points or traits (i.e. how is Twin 1's vegetable liking at 15 months associated with Twin 2's vegetable liking at 3 years) (Plomin et al., 2008; Rijsdijk & Sham, 2002).

7.3.3.3.1. Twin correlations

The first step for investigating the longitudinal heritability of a trait at two time points is to establish whether the trait measurements at each time point are associated with one another at the level of the individual. Significant correlations across the time points (e.g. significant Pearson's correlations) suggest common influences at both time points. As described in Chapter 5, Pearson's correlations were calculated to explore the bivariate relationships between the FP scores across the two time points.

'Cross-twin/cross-trait', or in the case of longitudinal analyses 'cross-twin/cross-time' (CT/CT) correlations, are the foundation of multivariate heritability analyses. CT/CT correlations show how within a twin pair, twin 1's score for time point A (or trait A) varies in relation to twin 2's score for time point B (or trait B). The same theoretical inferences for univariate heritability analyses also apply for the cross-correlations. When comparing CT/CT correlations for two time points, higher monozygotic correlations compared with dizygotic correlations are indicative of a shared genetic influence driving the phenotypic association between the two time points. Conversely, very little difference between MZ and DZ cross-correlations suggests mainly common shared environment effects are influencing the phenotypic association across time points. If significant within-individual cross-time correlations are found but CT/CT correlations are not significant, it is likely that common unique environmental factors are driving the phenotypic correlations.

In order to explore the shared heritability between food preferences (FP) at 15 months and 3 years, CT/CT intraclass correlations (ICCs) were calculated for each of the five food groups across the two time points. For every food group, there were 2 CT/CT correlations: i.e. vegetable liking in twin 1 at 15 months correlated with vegetable liking in twin 2 at 3 years and vegetable liking in twin 1 at 3 years correlated with vegetable liking in twin 2 at 15 months. These correlations were compared with the phenotypic correlations calculated using Pearson's product moment correlation coefficients in order to identify evidence of an underlying common genetic influence for the traits at both time points. Twin correlations were conducted in SPSS version 20 for Windows.

7.3.3.3.2. Estimating longitudinal heritability using twin covariances

The modelling techniques used to estimate the shared genetic and environmental influences on a trait measured at multiple points are essentially the same as those used to estimate the total genetic and environmental influences on a single trait at a single time point. While univariate analyses model twin covariation across the same trait and time point, the multivariate analyses model twin covariation across different time points. Two modelling techniques are commonly used when estimating the longitudinal heritability of a trait across two time points using twin covariation, these are; the Cholesky Decomposition Model and the Correlated Factors Model.

A Cholesky Decomposition Model involving two phenotypes (i.e. the same trait at two time points) will provide two estimates of each of the A, C and E parameters. When conducting longitudinal analyses, the variable representing the trait measured at the first time point should be entered into the model first because the order in which the trait measures are entered effects the organisation of the covariance. The first estimates of A, C and E explain the variance in the first variable, along with covariance between the first and second variables. Whereas the second A, C and E estimates only explain residual variance in the second variable (variance independent of the first variable).

The Correlated Factors Model provides two pieces of information about shared genetic effects between the measured phenotypes; (i) pairwise aetiological correlations and (ii) bivariate heritability estimates. The aetiological correlations between the trait measurements indicate the extent to which the genetic (genetic correlation; r_g), shared environmental (shared environmental correlation; r_c) and unique environmental (unique environmental correlation; r_e) influences on trait 1 (i.e. time 1) also influence variance in trait 2 (i.e. time 2). It is important to note that the aetiological correlations are independent of the univariate heritability of each trait measurement, meaning it is possible to have very high estimates of genetic correlations when the individual heritability estimates for each trait measurement are very low. This eventuality may occur if genetic effects predicted very little of the phenotypic variance at one or both time point, but the few genes that are contributing influence both time points. Irrespective of the heritability of either trait measurement in a pair, a genetic correlation of 1.0 would show that all of the genetic influences on trait 1 (e.g. vegetable liking at 15 months) also influence trait 2 (e.g. vegetable liking at 3 years), and a value of 0 would indicate that the two trait measurements share no genes in common. The second set of information provided by the correlated factors model is the bivariate heritability estimates. These indicate the proportion of the phenotypic correlation between two trait measurements that can be explained by common genetic, common shared environment or common unique environmental influences. The sum of the three bivariate estimates is equal to the phenotypic correlation.

In summary, the aetiological correlations quantify the extent to which the same genetic factors or environments influence two phenotypes, while the bivariate estimates indicate the extent to which common factors (genetic, shared environmental or unique environmental) contribute to the observed phenotypic association. These multivariate models are more comprehensive than the separate univariate models and they provide a more complex interpretation of the genetic and environmental contributions to multiple phenotypes because they take into account relationships within twin pairs as well as relationships between the phenotypes. Including the food preferences traits measured at both ages in a single model enables comparisons of the magnitude of the genetic and environmental contributions to the trait at each time point.

Cholesky Decomposition Models and Correlated Factors Models were run to examine the shared genetic and environmental influences on each of the food preferences at 15 months (T1) and 3 years (T5).

7.3.3.4. Power

Heritability power calculations for the sample size at T1 of; 596 MZ pairs and 1275 DZ pairs, and at T5 of; 458 MZ pairs and 872 DZ pairs were conducted in Mx for univariate analyses. Power calculations were based on the smallest genetic and shared environmental effects reported in the previous heritability study of children's food preferences (Breen et al., 2006). In this study the smallest reported genetic effect was 20% (for 'desserts'; A=20%, C=64%, E=16%), and the smallest reported shared environment effect was 12% (for 'meat and fish'; A=78%, C=12%, E=10%). In keeping with these estimates, at T1 the sample is powered at 99.9% to detect a significant genetic effect of only 20% with a shared environment effect of 64%; the sample is powered at 89% to detect a significant shared environment effect of only 12%, with a genetic effect of 78%. The T5 sample is powered at 99.9% to detect a significant genetic effect of only 20% with a shared environment effect of 64%, and is powered at 77% to detect a significant shared environment effect of only 12%, with a genetic effect of 78%. Multivariate analyses (i.e. the longitudinal analyses) increase the power to detect both significant genetic and shared environmental effects compared to the univariate analyses.

7.4. Results

7.4.1. Summary statistics

A total of 3858 children had complete data for at least one of the FPQ scales at T1 (aged 15 months) and 2686 children had complete data for a minimum of one of the FPQ scales at T5 (aged 3 years). Missing data varied by FPQ scale (see Table 7.1 for participant numbers of each scale at each time point). For the longitudinal heritability analyses, a maximum of 2495 children had complete data on a given FPQ scale at both T1 and T5 and zygosity information (see Table 7.6 for the exact number of participants included in the CT/CT correlations for each food group). However, Mx uses a method of full-information maximum-likelihood (FIML) approach to the treatment of missing data. FIML assumes multivariate normality, and maximises the likelihood of the model given the observed data by including every participant with data on any of the phenotypes included in the model (Neale, Boker et al. 2003). Therefore the individual sample sizes for each of the longitudinal models varied and are shown in Table 7.7.

As heritability analyses require equal variances among MZ and DZ twins, variance for each food group were compared between MZ and DZ pairs. The Levene's test for equality of variance revealed no significant differences in variance by zygosity for any of the food groups at either age. Table 7.1 shows the mean food preference scores for each of the five food groups at T1 and T5 by zygosity group. There were no zygosity differences in the mean preference scores for any of the food group scales at either T1 or T5.

Table 7.1: Unadjusted means (standard deviations) and significance values for FPQ subscale scores by zygosity at T1 and T5

Scale	Time point[a] (n)	Mean (sd)			Student's T (*df*)	*P* value[c]
		All[b]	**MZ**	**DZ**		
Vegetable	**T1** (1862)	1.41 (0.71)	1.43 (0.70)	1.39 (0.71)	1.64 (3708)	0.102
	T5 (1301)	0.47 (0.61)	0.46 (0.60)	0.48 (0.62)	-0.61 (2611)	0.539
Fruit	**T1** (1862)	1.67 (0.58)	1.65 (0.59)	1.68 (0.58)	-1.62 (3709)	0.103
	T5 (1283)	0.91 (0.68)	0.90 (0.70)	0.92 (0.68)	-0.92 (2572)	0.357
Protein	**T1** (1843)	1.25 (0.64)	1.29 (0.60)	1.24 (0.65)	2.18 (3672)	0.030
	T5 (1256)	0.85 (0.59)	0.87 (0.57)	0.84 (0.59)	1.11 (2518)	0.269
Dairy	**T1** (1859)	1.81 (0.45)	1.80 (0.47)	1.81 (0.45)	-0.04 (3688)	0.968
	T5 (1284)	0.76 (0.59)	0.75 (0.58)	0.76 (0.60)	-0.36 (2575)	0.720
Snacks	**T1** (1798)	1.44 (0.53)	1.42 (0.51)	1.44 (0.54)	-0.80 (3581)	0.425
	T5 (1323)	1.42 (0.41)	1.42 (0.40)	1.41 (0.42)	0.52 (2646)	0.602

[a] Mean age at T1 was 15.8 months; mean age at T5 was 41.5 months (3.5 years)
[b] This includes the full sample with complete zygosity information for each scale
[c] An alpha of <0.01 was adopted throughout to account for the large sample and multiple tests

7.4.2. Univariate heritability analyses

7.4.2.1. Intraclass correlations

The MZ and DZ intraclass correlations for the five food groups are presented graphically in Figure 7.2, for T1 and in Figure 7.3, for T5. For every scale the MZ correlations were higher than the DZ correlations, indicating a genetic contribution to each food preference trait in both age groups. At T1 the size of the difference between MZ and DZ correlations was slightly smaller for snack foods compared to the other food groups, indicating a smaller contribution of genetic factors to snack food liking. Furthermore, the MZ correlations were very high overall indicating only a small influence of the unique environment on any trait (≤13%). At T5 (see Figure 7.3), the size of the difference between MZ and DZ correlations were larger for all of the food groups but again the smallest difference in intraclass correlations was for snack foods. Again, the MZ correlations were very high for all food groups suggesting small influences of the unique environment on liking for every food group at this age (≤13%).

The intraclass correlations for liking scores of each of the 84 individual foods measured at T5 (reported in Appendix 2.2.), revealed higher MZ than DZ correlation coefficients for every food. This indicates a consistent, though sometimes small, genetic contribution to liking for individual foods, as well as for food groups.

7.4.2.2. Model-fitting analyses

The ACE model-fitting analyses confirmed the results of the intraclass correlations. Details of the results from the various models that were tested for each of the food group preferences are shown in Table 7.2 to Table 7.5. The parameter estimates and goodness of fit statistics are shown for the full ACE model and for the three sub-models. For every FPQ subscale, at both ages, the full ACE model fitted the data best, as dropping either the genetic or shared environment components of variance (or both) led to substantial worsening of fit according to both criteria (i.e. Chi-square and Akaike Information Criterion).

7.4.2.2.1. Liking for vegetables

Vegetable liking showed clear heritability at both ages but the genetic influence increased from 31% at T1 to 50% at T5. The reverse pattern was shown for the estimated shared environment effect which was also substantial at both ages but decreased from 57% at T1 to 39% at T5. The influence of the non-shared environment was low at both T1 and T5; 12% and 11% respectively.

7.4.2.2.2. Liking for fruit

The largest heritability estimate of all the food groups was observed for fruit liking at both ages. At T1 the genetic influence was moderate at 43% but at T5 it increased to 57%. The influence of the shared environment at T1 was virtually the same as the genetic influence (44%) but at T5 the shared environmental effect was lower (30%). Again the effect of the non-shared environmental was relatively small and comparable in both age groups (13% for both T1 and T5).

7.4.2.2.3. Liking for Protein

The largest difference between heritability estimates of food preferences at T1 and T5 was observed for Protein foods. The estimate of the genetic effect on protein preference was modest at T1 (23%) but much higher at T5 (49%) while the reverse was true for the shared-environmental effect which was large at T1 (72%) but much smaller at T5 (34%). The effect of the non-shared environment was estimated to be very low at T1 (5%) and was slightly larger at T5 (16%).

Figure 7.2: Correlations (and 95% CI) between twin pairs for food group preference scores by zygosity at T1.

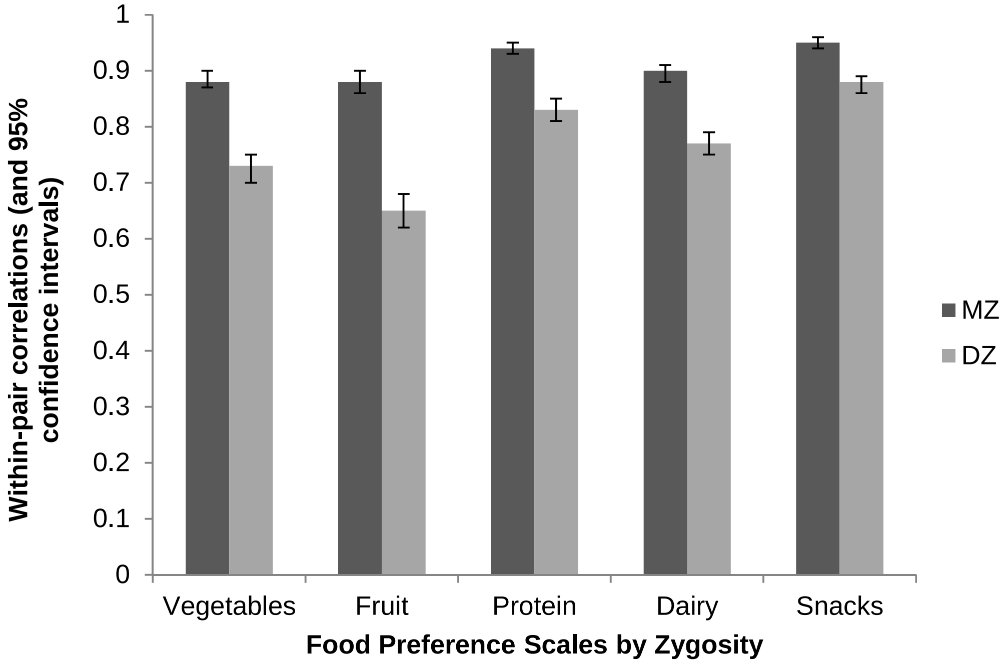
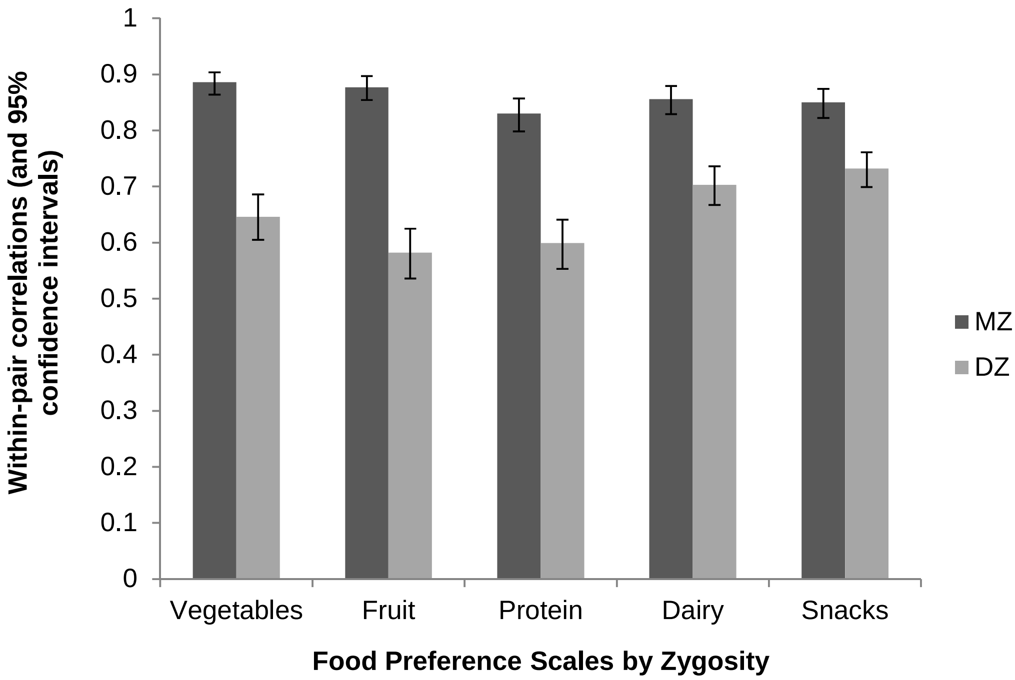


Figure 7.3: Correlations (and 95% CI) between twin pairs for food group preference scores by zygosity at T5.



7.4.2.2.4. Liking for dairy foods

Preference for dairy foods showed low to moderate heritability in both age groups compared to most other food groups. The genetic effect on liking for dairy foods was estimated at only 22% at T1 and 32% at T5. The effect of the shared environment on liking was moderate to large by comparison, estimated at 67% for T1 and slightly less, 54% at T5. In keeping with estimates for the other food preferences, the influence of the non-shared environment on liking for dairy foods was small at T1 (11%) and T5 (14%).

7.4.2.2.5. Liking for snack foods

The smallest estimated genetic influence of all the food group preferences was seen for snack foods at both T1 (16%) and T5 (27%) respectively. In both age groups, the majority of the variance in this trait was explained by the shared environment. This observation was even clearer at T1, where 79% the variance in liking for snack food was explained by shared environmental effects, than at T5 when it was still large but slightly lower at 59%. The influence of the non-shared environment on this trait was very small at T1 (5%) and remained small at T5 (14%).

Table 7.2: Parameter estimates (95% confidence intervals) for food preferences at T1 [a]

Scale (n)[b]	**Model**[c]	**Additive Genetic Effect (A)**	**Shared Environment Effect (C)**	**Unique Environment Effect[d] (E)**
Vegetables	**ACE***	**0.31 (0.26-0.36)**	**0.57 (0.52-0.62)**	**0.12 (0.10-0.13)**
(3724)	CE	-	0.78 (0.76-0.80)	0.22 (0.20-0.24)
	AE	0.89 (0.88-0.90)	-	0.11 (0.10-0.13)
	E	-	-	1.00 (1.00-1.00)
Fruit	**ACE***	**0.43 (0.37-0.50)**	**0.44 (0.38-0.50)**	**0.13 (0.11-0.14)**
(3726)	CE	-	0.73 (0.71-0.75)	0.27 (0.25-0.29)
	AE	0.88 (0.86-0.89)	-	0.12 (0.11-0.14)
	E	-	-	1.00 (1.00-1.00)
Protein	**ACE***	**0.23 (0.20-0.26)**	**0.72 (0.68-0.75)**	**0.05 (0.05-0.06)**
(3688)	CE	-	0.87 (0.86-0.88)	0.13 (0.12-0.14)
	AE	0.94 (0.93-0.95)	-	0.06 (0.05-0.07)
	E	-	-	1.00 (1.00-1.00)
Dairy	**ACE***	**0.22 (0.18-0.27)**	**0.67 (0.63-0.71)**	**0.11 (0.10-0.12)**
(3721)	CE	-	0.82 (0.80-0.83)	0.18 (0.17-0.20)
	AE	0.89 (0.88-0.90)	-	0.11 (0.10-0.12)
	E	-	-	1.00 (1.00-1.00)
Snacks	**ACE***	**0.16 (0.14-0.19)**	**0.79 (0.77-0.82)**	**0.05 (0.04-0.05)**
(3597)	CE	-	0.90 (0.89-0.91)	0.10 (0.09-0.11)
	AE	0.95 (0.94-0.95)	-	0.05 (0.05-0.06)
	E	-	-	1.00 (1.00-1.00)

[a] Adjustments to scores: scores modelled were residuals adjusted for age of the child when the parent completed the FPQ and sex.

[b] Sample: presented models include all infants with valid data for age, sex and the FPQ scale score at T1.

[c] Statistical analyses: Standard ACE model-fitting analyses for continuous data were used. CE, AE and E models are nested within the full ACE model. The ACE model dissects the phenotypic variance into A, C and E; the CE model drops the A parameter and assesses variance explained by C and E only; the AE model drops the C parameter and assesses the variance explained by A and E only; the E model drops both the A and C parameters and assesses the variance explained by E only.

[d] Includes measurement error.

* The best-fitting model for each scale is **bolded**.

Table 7.3: ACE model fit statistics for food preferences at T1

Scale (n)	**Model**[b]	**-2LL**[a]	**df**[a]	**AIC**[a]	**Δ AIC**	**$\Delta\chi^2$ (df)**	***P***
Vegetable	**ACE***	**8708.32**	**3719**	**1270.32**	**-**	**-**	**-**
(3724)	CE	8840.61	3720	1400.61	130.29	132.29 (1)	<0.001
	AE	8970.37	3720	1530.37	260.05	262.05 (1)	<0.001
	E	10576.25	3721	3134.25	1863.93	1867.93 (2)	<0.001
Fruit	**ACE***	**8973.63**	**3720**	**1533.63**	**-**	**-**	**-**
(3726)	CE	9153.07	3721	1711.07	177.43	179.43 (1)	<0.001
	AE	9105.71	3721	1663.71	130.08	132.08 (1)	<0.001
	E	10557.01	3722	3113.01	1579.38	1583.38 (2)	<0.001
Protein	**ACE***	**7637.25**	**3683**	**271.25**	**-**	**-**	**-**
(3688)	CE	7854.23	3684	486.23	214.99	216.99 (1)	<0.001
	AE	8195.24	3684	827.24	555.99	558.00 (1)	<0.001
	E	10423.70	3685	3053.70	2782.45	2786.45 (2)	<0.001
Dairy	**ACE***	**8419.43**	**3716**	**987.43**	**-**	**-**	**-**
(3721)	CE	8510.85	3717	1076.85	89.42	91.42 (1)	<0.001
	AE	8813.46	3717	1379.46	392.04	394.04 (1)	<0.001
	E	10539.89	3718	3103.89	2116.47	2120.47 (2)	<0.001
Snacks	**ACE***	**7115.33**	**3592**	**-68.67**	**-**	**-**	**-**
(3597)	CE	7279.80	3593	93.80	162.48	164.48 (1)	<0.001
	AE	7908.69	3593	722.69	791.36	793.36 (1)	<0.001
	E	10227.68	3594	3039.69	3108.36	3112.36 (2)	<0.001

[a] Abbreviations: -2LL, -2 log likelihood; df, degrees of freedom; AIC, Akaike's Information Criterion.

[b] Statistical analyses: Standard ACE model-fitting analyses for continuous data were used. CE, AE and E models are nested within the full ACE model. The ACE model dissects the phenotypic variance into A, C and E; the CE model drops the A parameter and assesses variance explained by C and E only; the AE model drops the C parameter and assesses the variance explained by A and E only; the E model drops both the A and C parameters and assesses the variance explained by E only.. Two fit indices are reported from the structural equation modelling analyses to evaluate sub-models against the full ACE model: *P* value based on the likelihood ratio chi-square test and Akaike's Information Criterion (AIC).

* The best-fitting model for each scale is **bolded**.

Table 7.4: Parameter estimates (95% confidence intervals) for food preferences at T5[a]

Scale (n)[b]	**Model**[c]	**Additive Genetic Effect (A)**	**Shared Environment Effect (C)**	**Unique Environment Effect[d] (E)**
Vegetables	**ACE***	**0.50 (0.42-0.56)**	**0.39 (0.32-0.46)**	**0.11 (0.09-0.13)**
(2606)	CE	-	0.73 (0.70-0.75)	0.27 (0.25-0.30)
	AE	0.89 (0.88-0.90)	-	0.11 (0.10-0.12)
	E	-	-	1.00 (1.00-1.00)
Fruit	**ACE***	**0.57 (0.49-0.66)**	**0.30 (0.21-0.38)**	**0.13 (0.11-0.15)**
(2574)	CE	-	0.69 (0.66-0.71)	0.31 (0.29-0.34)
	AE	0.87 (0.86-0.89)	-	0.13 (0.11-0.14)
	E	-	-	1.00 (1.00-1.00)
Protein	**ACE***	**0.49 (0.41-0.59)**	**0.34 (0.26-0.42)**	**0.16 (0.14-0.29)**
(2522)	CE	-	0.67 (0.64-0.70)	0.33 (0.30-0.36)
	AE	0.84 (0.82-0.86)	-	0.16 (0.14-0.18)
	E	-	-	1.00 (1.00-1.00)
Dairy	**ACE***	**0.32 (0.25-0.39)**	**0.54 (0.48-0.60)**	**0.14 (0.12-0.16)**
(2577)	CE	-	0.76 (0.73-0.78)	0.24 (0.22-0.27)
	AE	0.86 (0.84-0.88)	-	0.14 (0.12-0.16)
	E	-	-	1.00 (1.00-1.00)
Snacks	**ACE***	**0.27 (0.21-0.34)**	**0.59 (0.53-0.65)**	**0.14 (0.12-0.16)**
(2648)	CE	-	0.77 (0.75-0.79)	0.23 (0.21-0.25)
	AE	0.87 (0.85-0.88)	-	0.14 (0.12-0.15)
	E	-	-	1.00 (1.00-1.00)

[a] Adjustments to scores: scores modelled were residuals adjusted for age of the child when the parent completed the FPQ and sex.

[b] Sample: presented models include all infants with valid data for age, sex and the FPQ scale score at T5.

[c] Statistical analyses: Statistical analyses: Standard ACE model-fitting analyses for continuous data were used. CE, AE and E models are nested within the full ACE model. The ACE model dissects the phenotypic variance into A, C and E; the CE model drops the A parameter and assesses variance explained by C and E only; the AE model drops the C parameter and assesses the variance explained by A and E only; the E model drops both the A and C parameters and assesses the variance explained by E only.

[d] Includes measurement error.

* The best-fitting model for each scale is **bolded**.

Table 7.5: ACE model fit statistics for food preferences at T5

Scale (n)	**Model**[b]	**-2LL**[a]	**df**[a]	**AIC**[a]	**Δ AIC**	**Δχ^2 (df)**	***P***
Vegetables	**ACE***	**6222.13**	**2608**	**1006.13**	**-**	**-**	**-**
(3724)	CE	6400.05	2609	1182.05	175.92	177.92 (1)	<0.001
	AE	6294.22	2609	1076.22	70.09	72.09 (1)	<0.001
	E	7374.49	2610	2154.49	1148.36	1152.36 (2)	<0.001
Fruit	**ACE***	**6283.27**	**2569**	**1145.27**	**-**	**-**	**-**
(3726)	CE	6458.48	2570	1318.48	173.21	138.21(1)	<0.001
	AE	6319.85	2570	1179.85	34.59	36.59 (1)	<0.001
	E	7274.14	2571	2132.14	986.87	990.87(2)	<0.001
Protein	**ACE***	**6277.97**	**2515**	**1247.97**	**-**	**-**	**-**
(3688)	CE	6390.10	2516	1358.10	110.13	112.13 (1)	<0.001
	AE	6325.23	2516	1293.23	45.26	47.26 (1)	<0.001
	E	7153.56	2517	2119.56	871.50	875.59 (2)	<0.001
Dairy	**ACE***	**6164.77**	**2572**	**1020.77**	**-**	**-**	**-**
(3721)	CE	6240.47	2573	1094.47	73.70	75.70 (1)	<0.001
	AE	6309.42	2573	1163.42	142.66	144.66 (1)	<0.001
	E	7322.03	2574	2174.03	1153.26	1157.26 (2)	<0.001
Snacks	**ACE***	**6268.34**	**2643**	**982.34**	**-**	**-**	**-**
(3597)	CE	6330.73	2644	1042.73	60.388	62.39 (1)	<0.001
	AE	6457.21	2644	1169.21	186.87	188.87 (1)	<0.001
	E	7517.93	2645	2227.93	1245.59	1249.59 (2)	<0.001

[a] Abbreviations: -2LL, -2 log likelihood; df, degrees of freedom; AIC, Akaike's Information Criterion.

[b] Statistical analyses: Standard ACE model-fitting analyses for continuous data were used. CE, AE and E models are nested within the full ACE model. The ACE model dissects the phenotypic variance into A, C and E; the CE model drops the A parameter and assesses variance explained by C and E only; the AE model drops the C parameter and assesses the variance explained by A and E only; the E model drops both the A and C parameters and assesses the variance explained by E only. Two fit indices are reported from the structural equation modelling analyses to evaluate sub-models against the full ACE model: *P* value based on the likelihood ratio chi-square test and Akaike's Information Criterion (AIC).

* The best-fitting model for each scale is **bolded**.

7.4.3. Longitudinal heritability analyses

For every trait measured, heritability appeared higher at T5, when the children were a mean age of 41.5 months (3.5 years) than at T1 when the children were a mean age of 15.8 months (1.3 years). However the relative magnitude of the genetic contribution to preferences among the food groups were the same at both time points, i.e. the food groups remained in the same sequential order from highest to lowest heritability; fruit, vegetables, protein, dairy and snacks. The largest increase in heritability estimates between the two time points was observed for protein (22% to 49%). The smallest observed changes in heritability were for dairy and snacks (22% to 32% and 16% to 27% respectively). Figure 7.4 compares the heritability at T1 and T5 graphically for liking of each food group.

In order to establish whether the same genes and/or shared environmental influences were behind food preferences at the two time points and to ascertain whether these apparent increases in heritability of food preferences with age were significant, it was necessary to conduct longitudinal heritability analyses.

7.4.3.1. Twin correlations

The longitudinal phenotypic correlations for each food are shown in Table 7.6. The correlations were all significant suggesting common influences are driving food preferences at 15 months and 3 years.

The CT/CT intraclass correlations for vegetables, protein, dairy and snack preferences at 15 months (T1) and 3 years (T5) were fairly similar for MZ compared to DZ twins, and the MZ correlations consistently fell within the confidence intervals of the DZ correlations, suggesting any small differences are not significant and that common genetic influences are not the main driver of the observed phenotypic longitudinal correlations in these preferences. For fruits, the MZ correlations were almost twice as large as the DZ correlations and fell outside the DZ confidence intervals, suggesting that common genetic factors play a more important role in explaining the longitudinal phenotypic correlation in liking for fruit. The fact that all the CT/CT correlations for MZ and DZ twins were significant, and fairly similar across foods, indicates that common shared environmental influences are contributing importantly to the correlation between liking for most food groups across the two time points. All CT/CT intraclass correlations are shown in Table 7.6.

Figure 7.4: Longitudinal model heritability estimates (95% confidence intervals) for food preference subscales at T1 and T5

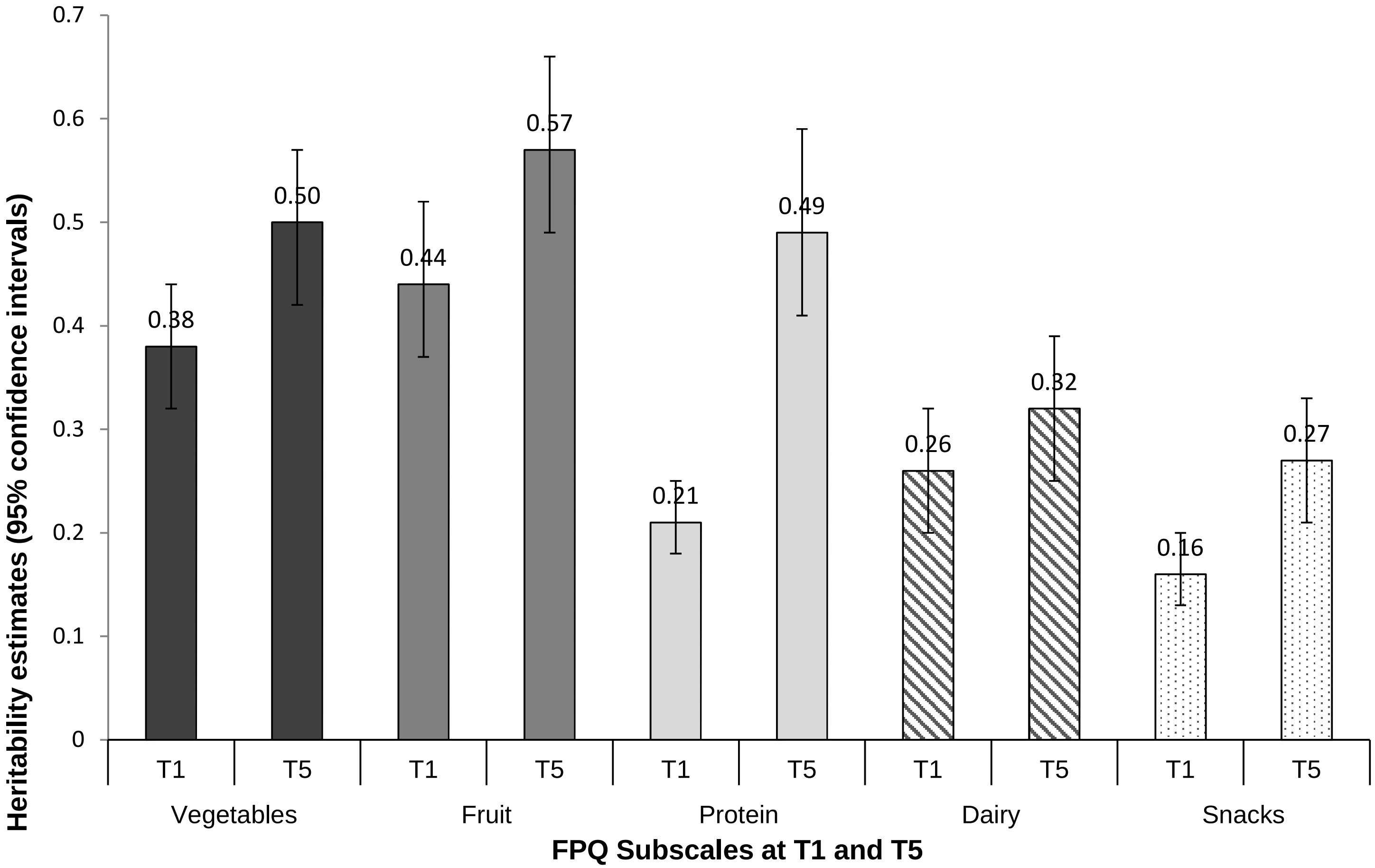


Table 7.6: Cross-twin cross-time intraclass correlations (and 95% CI) and phenotypic correlations for FPQ scores between T1 and T5.

Scale *(n)*	**Twin and time point**	**ICC (95% CI)**		**Phenotypic correlation**
		MZ	**DZ**	
Vegetables *(2495)*	Twin 1 T1*Twin 2 T5	0.17 (0.08-0.26)	0.16 (0.10-0.23)	0.22**
	Twin 2 T1*Twin 1 T5	0.19 (0.10-0.28)	0.20 (0.13-0.27)	
Fruit *(2453)*	Twin 1 T1*Twin 2 T5	0.30 (0.21-0.39)	0.16 (0.09-0.23)	0.30**
	Twin 2 T1*Twin 1 T5	0.33 (0.24-0.41)	0.18 (0.11-0.24)	
Protein *(2409)*	Twin 1 T1*Twin 2 T5	0.13 (0.03-0.22)	0.23 (0.16-0.29)	0.22**
	Twin 2 T1*Twin 1 T5	0.13 (0.04-0.23)	0.21 (0.14-0.28)	
Dairy *(2459)*	Twin 1 T1*Twin 2 T5	0.23 (0.14-0.32)	0.23 (0.16-0.30)	0.24**
	Twin 2 T1*Twin 1 T5	0.27 (0.18-0.36)	0.19 (0.12-0.25)	
Snacks *(2435)*	Twin 1 T1*Twin 2 T5	0.25 (0.16-0.34)	0.20 (0.13-0.26)	0.23**
	Twin 2 T1*Twin 1 T5	0.23 (0.14-0.32)	0.20 (0.13-0.27)	

**All phenotypic correlations were significant at an alpha level of <0.01

7.4.3.2. Longitudinal multivariate covariance models

7.4.3.2.1. Reproduced univariate ACE estimates

The estimates and confidence intervals for the total genetic (A), shared environmental (C) and unique environmental (E) contributions to each food preference and each time point are shown in Table 7.7. Estimates of heritability for all of the food group preferences at T5 were the same in the multivariate models as those provided by the univariate models already presented (vegetables; 50%, fruit; 57%, protein; 49%, dairy; 32% and snacks; 27%). The multivariate models produced largely comparable heritability estimates at T1 (vegetables; 38%, fruit; 44%, protein; 21%, dairy; 26% and snacks; 16%) compared to those from the univariate analysis (vegetables; 31%, fruit; 43%, protein; 23%, dairy; 22% and snacks; 16%) and the T1 estimates remained consistently lower than at T5 in the multivariate analyses. The reproduced univariate ACE estimates from the multivariate longitudinal models differ slightly from the simple univariate models because the parameter estimates are derived using more information in the multivariate analyses. The multivariate approach also has increased statistical power compared to univariate analyses, so smaller effects such as influences of the shared environment (which are often difficult to detect in univariate models) can be estimated more reliably. In addition, the sample included in the multivariate analyses was smaller than the full T1 sample, though largely similar to the T5 sample.

With the exception of dairy, all the T5 estimates of genetic influences on food preferences were outside the confidence intervals for the T1 estimates in each of the multivariate models (see Figure 7.4 for graphical illustration), indicating that the genetic influences on food preferences increased significantly with time. The reverse was true of shared environmental influences on food preferences in the longitudinal models. Estimates of shared environmental influences on food preferences at the two time points in the multivariate models were analogous to those from the univariate analyses (T1: vegetables; 54%, fruit; 43%, protein; 73%, dairy; 63% and snacks; 79% and T5: vegetables; 39%, fruit; 30%, protein; 34%, dairy; 54% and snacks; 59%). The influence of the shared environment on food preferences was lower for all food groups at T5 compared to T1, with the estimates at each time point falling outside the confidence intervals for the other time point, suggesting shared environmental influences on food preference traits decreased significantly over early childhood.

The multivariate models provided estimates of unique environmental influences on food preferences that were again largely comparable to those from the univariate analyses (T1: vegetables; 9%, fruit; 12%, protein; 5%, dairy; 11% and snacks; 5% and T5: vegetables; 11%, fruit; 13%, protein; 16%, dairy; 14% and snacks; 14%). The influence of the unique environment was lower at T1 than at T5 for each of the food groups, although these differences were small particularly for vegetables, fruits and dairy. The unique environment estimates for protein, dairy and snacks at each time point fell outside the confidence intervals for the other time point, suggesting these influences on food preferences increased between T1 and T5.

Table 7.7: ACE estimates (95% confidence intervals) for food preferences at T1 and T5 arising from the multivariate longitudinal models[a]

Scale (n)[b]	**Time point[c]**	**Additive Genetic Effect (A)**	**Shared Environment Effect (C)**	**Unique Environment Effect[d] (E)**
Vegetables (2652)	T1	0.38 (0.32-0.44)	0.54 (0.48-0.59)	0.09 (0.07-0.10)
	T5	0.50 (0.42-0.57)	0.39 (0.32-0.46)	0.11 (0.09-0.13)
Fruit (2655)	T1	0.44 (0.37-0.52)	0.43 (0.36-0.50)	0.12 (0.11-0.14)
	T5	0.57 (0.49-0.66)	0.30 (0.22-0.38)	0.13 (0.11-0.15)
Protein (2616)	T1	0.21 (0.18-0.25)	0.73 (0.70-0.77)	0.05 (0.05-0.06)
	T5	0.49 (0.41-0.59)	0.34 (0.26-0.42)	0.16 (0.14-0.19)
Dairy (2648)	T1	0.26 (0.20-0.32)	0.63 (0.58-0.68)	0.11 (0.09-0.13)
	T5	0.32 (0.25-0.39)	0.54 (0.48-0.60)	0.14 (0.12-0.16)
Snacks (2653)	T1	0.16 (0.13-0.20)	0.79 (0.76-0.82)	0.05 (0.05-0.06)
	T5	0.27 (0.21-0.33)	0.59 (0.53-0.65)	0.14 (0.12-0.16)

[a] Adjustments to scores: scores modelled were residuals adjusted for age of the child when the parent completed the FPQs and sex.
[b] Sample: presented models include all children with valid data for age, sex and the FPQ scale score at T1 and T5.
[c] Statistical analyses: A,C and E estimates provided by the longitudinal models; explaining the total variance in each food preference at each time point attributable to each parameter (A,C and E)
[d] Includes measurement error.

7.4.3.2.2. Contributions of 15 months ACE estimates to 3 years ACE estimates

The Cholesky Decomposition Models for each of the food groups at T1 (15 months) and T5 (3 years) are shown in Figure 7.5. to Figure 7.9. The estimates provided by the Cholesky Decomposition Models can be used to quantify the proportion of the total variance in food preferences at T5 that can be explained by common genetic, shared environmental and unique environmental influences from T1. For vegetables, protein, dairy and snacks only very small and non-significant proportion (0-2%) of the variance at T5 was explained by the same genetic factors driving these traits at T1. For liking for fruit a slightly higher and significant percentage of the variance at T5 was explained by genetic influences common to T1 (6%), although the majority of genetic influence at T5 was unique to this time point (51%). A significant (though still small) proportion of shared environmental effects at T5 were common to those at T1 (3-6%) for each food group. None of the unique environment factors influencing food liking at T1 were found to contribute to liking at T5 (all 0%).

Figure 7.5: Longitudinal Cholesky decomposition model of genetic and environmental influences on vegetable preference at T1 & T5

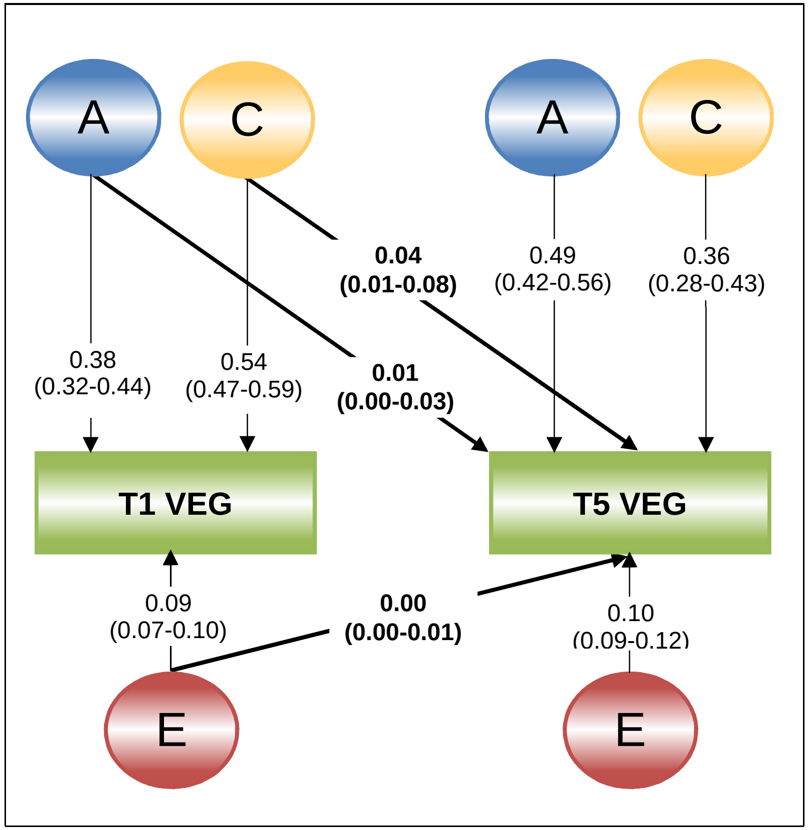
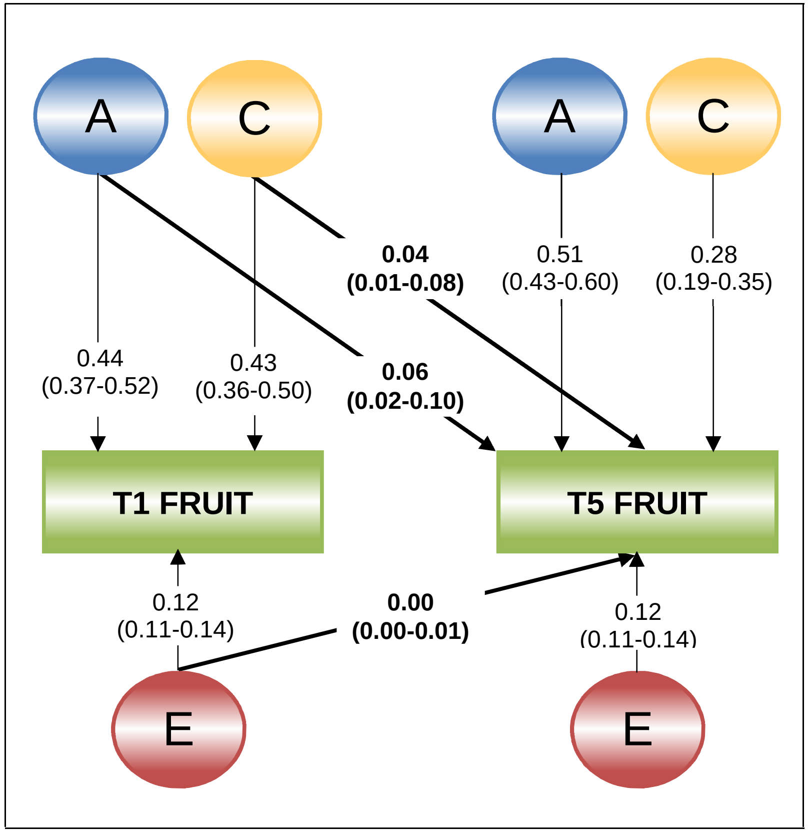


Figure 7.6: Longitudinal Cholesky decomposition model of genetic and environmental influences on fruit preference at T1 & T5



Path diagram showing genetic and environmental influences on food preference at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. This model breaks down the variance in a food preference at T5 into variance common with the food preference at T1 (**bold** diagonal single-headed arrows) and variance unique to the food preference at T5 (vertical single-headed arrows leading to the T5 food box). The vertical single-headed arrows on the left (pointing to the T1 food box) represent the total variance in the food preference, at T1 explained by A, C and E.

Figure 7.7: Longitudinal Cholesky decomposition model of genetic and environmental influences on protein preference at T1 & T5

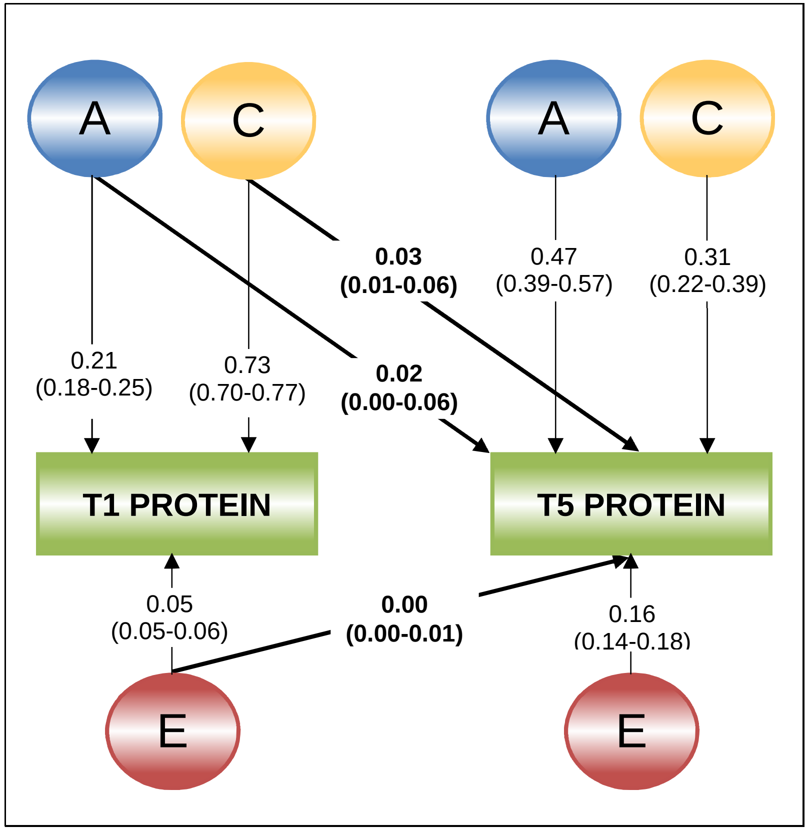
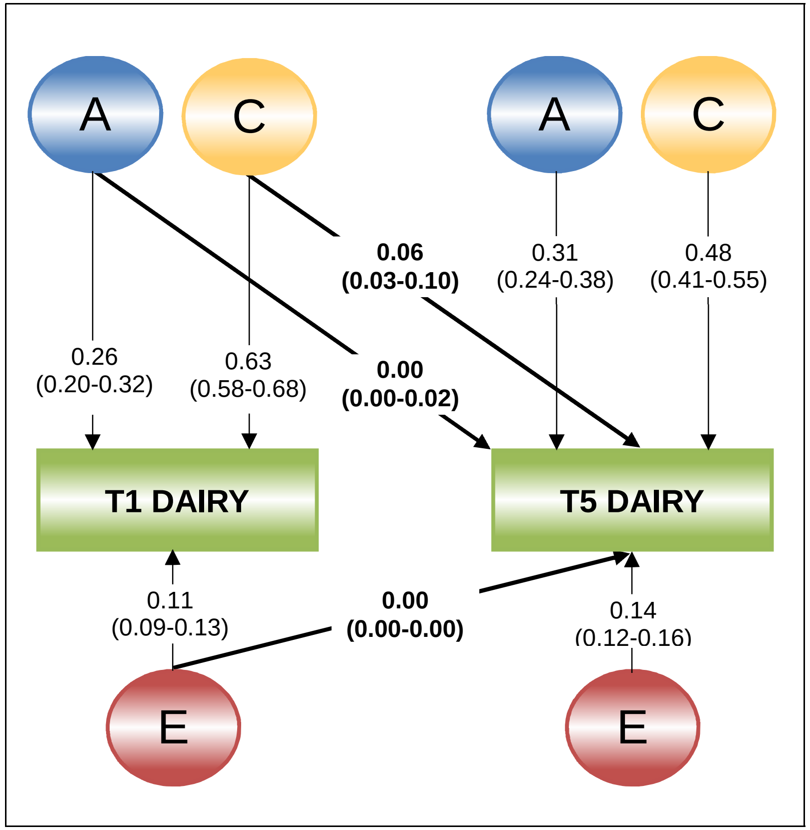
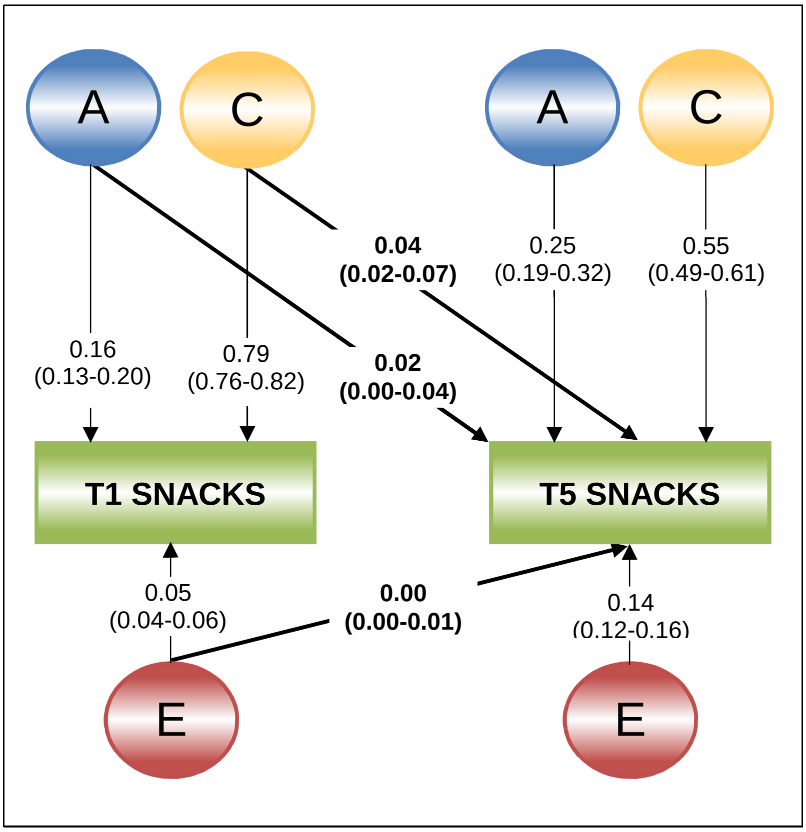


Figure 7.8: Longitudinal Cholesky decomposition model of genetic and environmental influences on dairy preference at T1 & T5



Path diagram showing genetic and environmental influences on food preference at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. This model breaks down the variance in a food preference at T5 into variance common with the food preference at T1 (**bold** diagonal single-headed arrows) and variance unique to the food preference at T5 (vertical single-headed arrows leading to the T5 food box). The vertical single-headed arrows on the left (pointing to the T1 food box) represent the total variance in the food preference, at T1 explained by A, C and E.

Figure 7.9: Longitudinal Cholesky decomposition model of genetic and environmental influences on snack preference at T1 & T5



Path diagram showing genetic and environmental influences on food preference at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. This model breaks down the variance in a food preference at T5 into variance common with the food preference at T1 (**bold** diagonal single-headed arrows) and variance unique to the food preference at T5 (vertical single-headed arrows leading to the T5 food box). The vertical single-headed arrows on the left (pointing to the T1 food box) represent the total variance in the food preference, at T1 explained by A, C and E.

7.4.3.2.3. Bivariate aetiological correlations

The genetic correlations (r_g) (shown in Table 7.8) for food preferences between the two time points were small to moderate (0.12-0.32) indicating relatively few genetic factors are shared across the two time points. Particularly small genetic correlations were found for vegetables and dairy foods (0.13 and 0.12 respectively) compared to fruit (0.32) and snacks (0.25) where a quarter to a third of genetic factors were common across the two age groups. The shared environment correlations (r_c) were higher overall (0.27-0.34) suggesting around one third of shared environmental influences on food preferences at T1 also influence at T5. The unique environmental correlations (r_e) were all small (0.01-0.21) indicating few unique environmental effects on food preferences are shared between the two age groups. Diagrams for the longitudinal Correlated Factors Models for each of the food groups are shown in Appendix 2.3.

7.4.3.2.4. Bivariate ACE estimates

The bivariate heritability estimates (shown in Table 7.8) indicated small but significant proportions of the longitudinal phenotypic associations for vegetable (26%), protein (30%) and snacks (23%) at 15 months and 3 years can be ascribed to common genetic factors. For most foods, the largest proportion of the longitudinal phenotypic correlations were driven by common shared environmental factors (vegetables; 64%, protein 66%, dairy; 84% and snacks; 78%), in keeping with the pattern observed in the CT/CT correlations (Table 7.6). However, for liking for fruit less than half (38%) of the longitudinal phenotypic correlation was apportioned to common shared environmental influences with common genetic influences explaining the largest proportion for this trait (54%). For all foods the proportion of the phenotypic correlation arising from common unique environmental influences was small, and with the exception of vegetables (9%) and fruit (7%), the bivariate E estimates for these traits did not reach significance. This suggests that for each food, there are common shared environmental factors contributing significantly to the covariation between these traits at 15 months and 3 years. While for all foods apart from dairy (for which the bivariate A estimate was not significant), common genetic factors are also contributing to the longitudinal covariation between these traits but to varying extents.

Table 7.8: Parameter estimates for covariance and common genetic, shared environmental and unique environmental effects underlying food preferences at 15 months and 3 years

Scales[a]	Phenotypic correlations[b] (95% CIs)	Variance components for bivariate A, C and E[c] (as % of phenotypic correlation[d])			Aetiological correlations[e] (95% CIs)		
		A	C	E	r_g	r_c	r_e
Vegetables T1/T5	0.22 (0.17, 0.28)	0.06 (26)*	0.14 (64)*	0.02 (9)*	0.13 (0.02, 0.24)	0.31 (0.19, 0.44)	0.21 (0.12, 0.30)
Fruit T1/T5	0.29 (0.24, 0.34)	0.16 (54)*	0.11 (38)*	0.02 (7)*	0.32 (0.21, 0.42)	0.31 (0.13, 0.47)	0.17 (0.07, 0.27)
Protein T1/T5	0.24 (0.18, 0.29)	0.07 (30)*	0.16 (66)*	0.01 (3)	0.22 (0.10, 0.33)	0.31 (0.19, 0.42)	0.09 (-0.01, 0.18)
Dairy T1/T5	0.24 (0.19, 0.29)	0.03 (14)	0.20 (84)*	0.00 (1)	0.12 (0.04, 0.17)	0.34 (0.24, 0.44)	0.03 (-0.07, 0.12)
Snacks T1/T5	0.23 (0.18, 0.29)	0.05 (23)*	0.18 (78)*	0.00 (1)	0.25 (0.11, 0.40)	0.27 (0.19, 0.35)	0.01 (-0.10, 0.09)

[a] Longitudinal comparisons of food preferences scales at T1 (15 months) and T5 (3 years)

[b] Longitudinal phenotypic correlation derived from structural equation modelling

[c] Proportion of variance in the phenotypic correlation that is explained by common additive genetic influences, common shared environmental and common non-shared environmental influences. The sum of the bivariate components equals the phenotypic correlation. * indicates significant bivariate estimates.

[d] The proportions of variance in the phenotypic correlations (accounted for by additive genetic effects, shared environment effects and unique environment effects) converted to percentages for ease of interpretation.

[e] r_g, genetic correlation; r_c, shared environmental correlation r_e, unique environmental correlation. A genetic, shared environmental or unique environmental correlation is significant if the 95% confidence interval does not include zero; all r_g and r_c correlations in the model were statistically significant.

7.5. Discussion

7.5.1. Summary of findings

This study set out to investigate the relative influences of genes and environment on liking for a range of food groups in children at two developmental stages – during late infancy, age 15 months (T1) and early childhood, age 3 years (T5). The results confirmed that there was moderate heritability of liking for most food groups measured at both time points and findings also indicate that heritability increased from 15 months to 3 years for these preferences. The highest heritability estimates, relative to each age group were for liking for fruit, although heritability estimates for liking of vegetables and protein were both substantial in the older age group (T5). Liking for two food groups; snacks and dairy, appeared to be less influenced by genes, with the environment playing a more important role in both age groups.

The results of these analyses provide support for earlier research indicating that variations in food preference are heritable, particularly when aggregated across empirically-derived groupings of foods (Breen et al., 2006), as was the case at age 3. The findings were broadly similar to the previous twin study in a similar age group (Breen et al., 2006), which also showed a stronger genetic effect for fruits and vegetables and a stronger shared environment effect for snacks and desserts. However, the finding of higher heritability of liking for protein foods reported in the previous study, involving similarly aged (4-5 years) preschool twins from the Twins Early Development Study (TEDS), was not observed here. Instead the genetic influence on liking for protein at T5 (49%) was almost identical to that for vegetables (50%) and lower than liking for fruit (57%). These differences may in part reflect the differences in the individual foods, grouped into the ‘protein’ categories of each study. The ‘protein’ food group for TEDS included three fish items, compared with only one type of fish (White Fish) included in the ‘protein’ category in the present analyses. Therefore, it is possible that the increased genetic influence on liking for protein found in the earlier study was largely being driven by liking of fish, not meat. However, given that liking for fish and meat items freely loaded together in the principal components analyses of both studies, this seems unlikely. In addition the TEDS sub-sample was not randomly selected and thus not representative of the full cohort. Two groups of families were identified for inclusion in the sub-sample; 100 families in which both parents were overweight or obese and 114 in which both parents were normal weight or lean

(Wardle, Sanderson, Guthrie, Rapoport, & Plomin, 2002). This sampling would result in an over-representation of children with a high genetic risk of obesity. Given there is some evidence to suggest that increased protein intake is associated with obesity in early life (Singhal et al., 2002; Singhal et al., 2010; Z. Yang & Huffman, 2013) this sampling bias may have contributed to the different heritability estimate for protein preference observed in the TEDS study. However, sample size was small (214 twin pairs) and the confidence intervals were large, so it is more likely due to chance. The present results should be considered more robust because of their larger sample size and smaller confidence intervals.

Interestingly, the food category displaying the highest heritability of liking in both age groups was fruits. Broadly speaking, this replicated the results of the earlier TEDS study which reported 51% heritability for fruit liking compared to 37% heritability for vegetable liking. While estimated heritability of vegetable liking was higher for the comparable age group (T5; 3 years) in the current analyses (50%), the heritability of liking for fruit was higher still (57%). However, the confidence intervals of the heritability estimates for vegetables (0.20-0.58) and fruit (0.37 - 0.68) in the TEDS study overlapped widely with those in the present analyses (vegetables; 0.42-0.56, fruit 0.49 - 0.66). The authors of the TEDS study describe how the finding of higher heritability for fruits than vegetables may be surprising considering the evidence from studies on 6-n-propylthiouracil (PROP) tasting (Tepper et al., 2009), indicating genetically determined bitter taste receptors that potentially influence vegetable liking (Breen et al., 2006). However, these findings do not negate the fact that PROP sensitivity may have some influence on heritability of vegetable preference. The vegetable category used in the current analyses involved a variety of edible plants including; root, leaf, seed and flowering vegetables and in turn these vegetables had varying taste components with different levels of ‘sweet’ and ‘bitter’ tastes. These findings of only a moderate heritability of vegetable preference suggests that while PROP sensitivity may play a role in preference for cruciferous more ‘bitter’ tasting vegetables, there are further genetic influences contributing vegetable preferences more generally and overall these do not seem to be as strong as those contributing to fruit preference in late infancy and early childhood.

The finding of a strong environmental influence on preference for dairy foods is entirely novel. The patterns of heritability for dairy preference are similar to those for snack foods at both time points and environmental factors seem to have the strongest influence on both these preference traits at 15 months and 3 years. These findings are consistent with the low heritability and strong shared environment effect reported for ‘Dessert’ preference in the TEDS sample (Breen et al., 2006). While some of the individual foods included in the dairy category at T5 are nutrient-dense (i.e. eggs and hard cheese), others (i.e. cream, custard and mayonnaise) that comprised this category in the current study are also high in energy. The similar pattern of heritability observed among energy-dense ‘snacks’ and ‘dairy’ foods, at least at the T5 time point, may therefore result from the high energy density of many of the individual foods that comprised the ‘dairy’ category.

Shared environment effects were strong for all foods at T1 and most foods at T5, although shared environment estimates for liking for vegetable, fruit and protein were not large at 3 years of age and the influence of the shared environment decreased for all foods over time. This is consistent with evidence indicating that in early life, food preferences are strongly influenced by experiences including exposure in utero, during milk feeding and through the weaning stage, and parental modelling (Harris, 2008; Mennella et al., 2001; Mennella & Trabulsi, 2012) .

The greater relative importance of the shared environment for food preferences in late infancy, compared with at age three, also fits well with the concept of an increased plasticity in food preference learning during early life (Birch, 1998a; Birch et al., 1998; Cashdan, 1994). The slightly reduced influence of the shared environment on liking for vegetables, fruits and protein foods, in combination with the increased genetic influence, observed in the 3 year old age group, may in part result from developmental increases in neophobia and food fussiness. In the previous chapter, it was reported that food fussiness was strongly related to liking for vegetable, fruit and protein foods and previous research indicates that neophobia and pickiness are associated with reduced intake and liking for these foods (Cooke et al., 2006; Galloway et al., 2003; Howard et al., 2012). Furthermore neophobia and pickiness are low in infancy but increases in these traits are commonly observed from around two years of age (Cooke et al., 2007). It is possible that the same genes influencing neophobia or pickiness are also affecting liking for some foods (i.e. vegetables and fruits) in young children.

Non-shared environmental effects were low for all five food groups at both 15 months and 3 years (11 to 19%). This is unsurprising given the relatively young age of the children in both samples. Before starting school, the majority of children’s food encounters and experiences occur within the family or home environment. However, the pattern of influence might change as the children grow up, acquire a level of autonomy and start to experience frequent eating occasions independent of their family. In a classroom setting food modelling by peers has been shown to strongly influence patterns of preference, for example (Greenhalgh et al., 2009; Hendy & Raudenbush, 2000).

With the exception of the TEDS study (already described), there has been limited evidence of heritability for food preferences. Some family studies comparing parents and children described comparatively low correlations for food preferences (Borah-Giddens & Falciglia, 1993); but as discussed in Chapter 1, this may result from the age differences between parents and children, supported by sibling studies indicating sibling pairs show more similarity in food preferences than parent–child pairs. Twin studies provide a better evaluation of genetic effects but there have been few studies with large enough samples to provide robust heritability estimates and only one (TEDS) used quantitative genetic modelling techniques to provide ACE estimates. A small number of previous twin studies carried out on preferences for ‘real foods’ (as opposed to specific tastes or flavour compounds) have provided limited evidence for a heritable component to liking for some foods, reporting higher MZ than DZ correlations for broccoli, strawberries, green beans and chicken (Falciglia & Norton, 1994; Krondl et al., 1983; Rozin & Millman, 1987), while others have found no evidence of genetic effects on food preference (Fabsitz et al., 1978; Faust, 1974; Greene et al., 1975). However, with the exception of the TEDS study (Breen et al., 2006), preferences were only examined for a very limited range of individual foods, sample sizes were low (< 72 pairs) and confidence intervals were not reported; making it likely that null findings resulted from limited power to detect anything other than very large genetic effects.

The findings from the longitudinal heritability analyses suggest few of the genetic influences driving preferences at 15 months are contributing to the heritability of these traits at 3 years. A slightly higher proportion of the shared environmental influences contributing food preferences were common across the two ages (r_c =0.31 for vegetables, fruit and protein).

7.5.2. Limitations

This study is the first to investigate the relative influences of genes and environment on food preferences for specific categories of foods at two separate time points in the same cohort. Furthermore the sample sizes used in these analyses were far higher than any previous study investigating the heritability of food preferences in children, providing greater power to detect moderate-sized genetic effects and more reliable estimates. These findings provide clear evidence for the heritability of preferences for food categories and an increase in heritability from infancy to early childhood. However, some caution must be exercised when interpreting the results. While the preference scores used in the older sample were aggregated across empirically-derived groupings of foods, consisting of a large number of individual food items, the preference ratings in the younger age group were derived from one or two generalised questionnaire items. This may have limited phenotypic variation, reduced the reliability of the preference measures used at 15 months (T1) and inflated differences between the two age groups. However, preferences for the five food groups measured showed similar patterns of genetic and environmental influence at both time points and the confidence intervals were relatively small for all the parameters in both age groups measured, indicating robust estimates.

The results at both time points rely on parental reports of children's food preferences, because children under 5 cannot report their own food preferences reliably from food lists (Hammond, Nelson, Chinn, & Rona, 1993) and observations of the behavioural expression of these traits would be unfeasible given the sample size. However, the differential pattern of heritability across the food groups, replicated in both age groups, appears to reject the case for simple parental bias.

Estimating heritability using the twin design has received some criticism based on the argument that shared environments are more similar for MZ than for DZ twins, which would inflate heritability estimates. However, studies that have tested this assumption have found no differences in the treatment of MZ and DZ twins (Kendler, Neale, Kessler, Heath, & Eaves, 1994; Loehlin & Nichols, 1976). Another potential issue that has been raised is parental rating bias; it has been suggested that parents of MZ twins may rate them more similarly than they actually are because they believe them to be identical, or parents of DZ twins may rate them as more dissimilar than they actually are. Parental rating bias for eating behaviours was tested in the Gemini cohort by comparing if parents who misclassified their twins' zygosity (i.e. they thought they were DZs when they were in fact MZs and vice versa) according to the zygosity questionnaire, rated their twins as more or less similar than those parents who correctly classified their twins' zygosity. The findings showed twin correlations were the same between the different subgroups and estimates of heritability were also very similar indicating they were not influenced by parental bias (Llewellyn, 2011).

Another criticism is that twins are too dissimilar from singleton children to allow for generalisations to the wider population (Bouchard & McGue, 2003). There is much research that has addressed these two arguments and reasoned against these criticisms of the twin design (Boomsma, Busjahn, & Peltonen, 2002; Bouchard & McGue, 2003; Derks, Dolan, & Boomsma, 2006; Klump, Holly, Iacono, McGue, & Willson, 2000). Additionally, convincing support for the use of twin studies in assessing genetic contributions to behavioural traits comes from the field of molecular genetics where specific polymorphisms on a single gene (single nucleotide polymorphisms, or SNPs), are being located that relate to traits found to be heritable, such as variants of TAS2R38, influencing bitter taste perception (Bufe et al., 2005). To date few reliable SNPs have been found to relate specifically to food preferences. Although recent studies using genome-wide complex trait analysis (GCTA), which estimates the total variance in a complex trait that can explained by all the available common SNPs on the whole genome, rather than just a single SNP, are supporting the heritability estimates produced by twin comparison studies (J. Yang, Lee, Goddard, & Visscher, 2011).

7.5.3. Conclusion

Genetic influences on food preferences appear to increase over time from infancy to early childhood. The findings are in keeping with observations made for a number of other behavioural traits (Bergen et al., 2007; Klump, McGue, et al., 2000; Simonen et al., 2004). These results suggest that while the influence of genes on food preference traits is moderate in early childhood, the relative influences of genes and environment may continue to change in later childhood and adolescence. These changes in heritability over time may result from: (a) different genes influencing preferences at different ages; (b) the same genes influencing preferences at the two ages but genetic effect sizes increasing so the expression of the genes gets stronger with age; (c) reductions in environmental variance (e.g. as exposure to food variety increases with age, individual variations in exposure may decrease); or (d) the occurrence of genotype-environment correlations (when exposure to environmental conditions depends on an individual's genotype). The current findings could potentially provide some support for several of these explanations. However, as discussed, the food preference measures were not identical across the two age groups and this may have contributed to the relatively small longitudinal phenotypic correlations observed. It seems likely that increases in heritability over time at least in part result from genotype-environment correlations, whereby individuals with a greater preference for certain foods seek out these foods, increasing their environmental exposure to them and thereby reinforcing their preferences.

Another question arising from these findings is whether the same or different genes are involved in influencing preferences for each of the five food groups measured here. It is interesting that preferences for the food groups displaying the same patterns of heritability have also been shown to correlate more highly (see Chapter 5) including vegetables and fruits (T1; r = 0.36, T5; r = 0.50), vegetables and protein (T1; r=0.31, T5; r=0.34) and dairy and snacks (T5; r = 0.30) suggesting that the same underlying pathways could be involved in their aetiology. Furthermore, in Chapter 6 it was reported that the eating behaviour trait food fussiness was highly associated with food preferences, particularly for vegetables and fruits. Given these findings, a multivariate genetic analysis of the covariance among the food group preferences and food fussiness would increase our understanding of the heritability of food preferences in children. Chapter 8 focuses on the shared pathways underlying preferences for different food groups and food fussiness in early childhood.

In conclusion, this study provides reliable evidence that food preferences in early childhood are influenced by a combination of genetic and shared environmental influences. It seems that for some nutrient-dense foods, particularly vegetables, fruits and protein foods, parents are correct in perceiving their children's preferences to be inborn. For other foods such as 'dairy' foods and energy-dense 'snacks', these results supports the health professionals' view that the home environment is the main determinant of children's liking.

CHAPTER 8 . STUDY 4: SHARED PATHWAYS UNDERLYING FOOD PREFERENCES AND FOOD FUSSINESS

8.1. Background

Chapter 5 demonstrated that, in 3 year old children, preferences for fruits vegetables, protein, dairy and snack foods are distinct from one another, to the extent that they emerged as statistically independent factors in the principle components analyses. Additionally, within-subject comparisons of means indicated liking scores for each of the five food groups were significantly different from one another. However, liking for these foods was found to be interrelated, with all preferences significantly positively correlated with one another at 3 years. The strongest of these correlations between food groups was found for vegetables and fruits. Findings from Chapter 6 also illustrate a strong association between the eating behaviour trait of food fussiness and food preferences, particularly preferences for vegetables. This relationship between increased fussiness and decreased acceptance of specific foods, such as fruits and vegetables has also been observed previously (Dovey et al., 2008; Galloway et al., 2003; Jacobi et al., 2003).

Chapter 7 provided evidence for substantial genetic influence on preferences for vegetables, fruits, protein foods and to a lesser degree dairy and snack foods in early childhood. Previous research has demonstrated a considerable heritable component to children's eating behaviours (Carnell, Haworth, Plomin, & Wardle, 2008; Llewellyn, van Jaarsveld, Boniface, Carnell, & Wardle, 2008; Llewellyn, van Jaarsveld, Johnson, Carnell, & Wardle, 2010), with a particularly strong genetic influence found for neophobia in early childhood (Cooke et al., 2007; Faith et al., 2013). Given the affinity between the constructs of neophobia and fussiness (described in detail in Chapter 1), it might be expected that fussiness would be similarly genetically determined.

These patterns of associations between food preferences and food fussiness give rise to questions about the shared aetiology of these traits. Are they associated because they share genetic influences in common or because the same environmental predictors are driving them? A multivariate analysis of the genetic and environmental influences on food fussiness and food preferences would help address these questions, while also providing total estimates of the genetic, shared environmental and unique environmental influences on these traits. This makes it possible to quantify the extent to which genetic and environmental influences are contributing to food fussiness, as well as providing estimates of the common genetic influences and common environmental influences that are contributing to the observed phenotypic correlations among the food preference and food fussiness traits. A multivariate approach also has increased power, which makes it possible to detect small effects that may not have reached significance in the simpler univariate models.

8.2. Study aims

The aim of this study is to; (a) assess the relative influences of genes and environment on food fussiness at 3 years of age; and (b) explore whether common genes or common environments underlie the associations between food preferences, and food fussiness in early childhood

8.3. Methods

8.3.1. Sample

This study involved twins from the Gemini cohort whose family completed the T5 questionnaire (n=2686) when the children were a mean age of 3.5 years. The characteristics of the cohort at this phase of data collection, as well as comparisons between this sample and the full Gemini cohort, have been described in detail in Chapter 4.

8.3.2. Measures

The food preference measures used in this study are those described in studies 1, 2 and 3 and have been explained in detail in the preceding chapters.

Food fussiness (FF) was measured at the same time as food preferences (in the T5 questionnaire). The FF scale forms part of the Child Eating Behaviour Questionnaire (CEBQ) and was designed to assess neophobic and ‘fussy’ or ‘picky’ eating traits in children (Wardle et al., 2001b). A full description of the FF scale, and the six individual items that comprise it, was provided previously in Chapter 6 of this thesis. Mean FF scores were calculated for each child, with higher scores indicated a greater food fussiness. Complete data was required on four out of six items for a FF score to be calculated.

All heritability analyses were conducted on food preference and food fussiness scores that had been residualised for age- and sex-effects using a regression procedure, described previously (see Chapter 7).

8.3.3. Univariate heritability of food fussiness analyses

The univariate heritability of food fussiness was investigated using two methods; intraclass correlations and quantitative genetic model-fitting analyses.

First, within-pair intraclass correlations were calculated for the residual food fussiness scores for MZ and DZ groups. A greater difference between the MZ and DZ correlations suggests higher heritability (see Chapter 7 for more detail on this method). Standard ACE model-fitting analyses were not conducted to provide univariate estimates of the genetic, shared environmental and unique environmental influences on food fussiness, as the multivariate model (described below) provides both univariate and multivariate estimates for all of the phenotypes included.

8.3.4. Multivariate heritability analyses

8.3.4.1. Twin correlations

The principals of multivariate heritability analyses were described more fully in Chapter 7. Longitudinal and cross-sectional multivariate analyses are essentially the same, with cross-twin/cross-trait (CT/CT) correlations forming the basis of all multivariate heritability analyses. In brief, CT/CT correlations show how within a twin pair, twin 1's score for trait A varies in relation to twin 2's score for trait B and higher correlations for MZ twins versus DZ twins indicate shared genetic influences are driving the phenotypic association between the two traits. In order to explore the shared heritability between food preferences (FP) and food fussiness (FF), CT/CT intraclass correlations (ICC) were calculated for; (i) each of the possible paired FP scale combinations, and also (ii) FF paired with each of the five food preferences. For every combination of FP/FP and FP/FF, there were 2 CT/CT correlations: i.e. vegetable preference in twin 1 correlated with fruit preference in twin 2 and fruit preference in twin 1 correlated with vegetable preference in twin 2; or FF in twin 1 correlated with vegetable preference in twin 2 and vegetables preference in twin 1 correlated with FF in twin 2. These correlations were compared with the phenotypic correlations calculated using Pearson's product moment correlation coefficients in order to identify evidence of an underlying common genetic influence for both traits. Twin correlations were conducted in SPSS version 20 for Windows.

<u>8.3.4.2. Covariance model-fitting</u>

Because the causal directions of the phenotypic associations between the variables in this study are unknown, a Correlated Factors Model (M.C. Neale & Maes, 2001; Plomin et al., 2008) was used to obtain estimates of independent and shared genetic influences on the FP and FF traits. The correlated factors model provides information about the univariate and the shared influences on the variables without assuming a causal direction from one variable to another.

As described previously in Chapter 7, this model provides two pieces of information about shared genetic effects between the measured phenotypes; (i) pairwise aetiological correlations and (ii) bivariate heritability estimates. The aetiological correlations quantify the extent to which common genetic factors or common environments influence two phenotypes (e.g. liking for vegetables and food fussiness), while the bivariate estimates indicate the extent to which common factors (genetic, shared environmental or unique environmental) contribute to the observed phenotypic association. The Correlated Factors Model also provides univariate estimates of heritability for each of the phenotypes included and can therefore be used to test the findings of the twin correlations and provide a more accurate estimate (and 95% CI's) of the heritability of food fussiness.

The covariance modelling was conducted using Mx Maximum-Likelihood Structural Equation Modelling Software (version 32; Virginia Commonwealth University, Richmond, VA).

8.4. Results

8.4.1 Twin correlations

<u>8.4.1.1. Intraclass correlations for food fussiness</u>

The MZ and DZ intraclass correlations for the FF scale are shown in Table 8.1. The MZ correlation was higher than the DZ correlation, indicating a genetic contribution to food fussiness. In addition, the DZ correlation was about half the MZ correlation suggesting a very minimal contribution of the shared environment, while the MZ correlations was high (0.84) indicating only a small influence of the unique environment (or error). These findings suggest genetic effects provide the largest contribution to variance in children's food fussiness.

Table 8.1: Intraclass correlations (ICCs) for food fussiness scale

Zygosity	ICC[a]	(95% CI[b])	N
MZ	0.84	(0.82 - 0.86)	458
DZ	0.35	(0.31 - 0.39)	872

[a] ICC, intraclass correlation
[b] CI, confidence interval

8.4.1.2. Cross-twin/ cross-trait food preference correlations

The pairwise CT/CT and phenotypic correlations between vegetable, fruit, protein, dairy and snack preferences are shown in Table 8.2. The CT/CT correlations between vegetable and fruit preferences were significant and moderate to large for MZ twins while the DZ correlations, although still significantly different from zero, were considerably smaller. This pattern of results indicates that for this pair of traits, shared genes are at least partially contributing to the observed phenotypic correlations. The phenotypic correlation between vegetable and fruit preferences (r=0.05) was also stronger than for any other paired combination of scales.

For the CT/CT associations between the remaining food preference scales, protein, dairy and snacks, the MZ correlations were largely similar to the DZ correlations and the MZ correlations consistently fell within the confidence intervals for the DZ correlations for at least one twin in each pairwise combination. This suggests that the phenotypic associations observed for these traits are largely explained by environmental effects rather than shared heritability.

8.4.1.3. Cross-twin/ cross-trait food preference and food fussiness correlations

The CT/CT correlations between each of the food preference scales and food fussiness, along with the phenotypic correlations are shown in Table 8.3. The CT/CT correlations between FF and vegetable liking, and FF and fruit liking, were significant for both MZ and DZ twins. These correlations were moderate to large for MZ twins but only half as large for DZ twins with no overlap of 95% confidence intervals. Again this suggests shared genes are at least partially contributing to the observed phenotypic correlations between FF and liking for vegetables, and FF and liking for fruits.

Significant CT/CT correlations were also observed between FF and protein and between FF and dairy for both MZs and DZs, with consistently higher MZ than DZ correlations in each pairwise combination. However, the difference between the magnitude of the MZ and DZ correlations were smaller for FF/protein and FF/dairy compared to FF/vegetables and FF/fruits. Additionally the confidence intervals for MZ and DZ correlations overlapped for at least one twin in each pairwise combination of FF with protein or dairy. The CT/CT correlations between FF and snacks revealed very small and non-significant MZ correlations. Taken together these findings suggest the majority of the phenotypic associations between food fussiness and liking for protein, dairy and snack foods is likely driven by environmental effects.

8.4.1.4. Cross-twin, cross-trait intraclass correlations; summary of findings

The largest phenotypic correlations were observed for liking for vegetables and fruit, liking for vegetables and FF and liking for fruit and food fussiness. Furthermore, the CT/CT correlations for these pairings of traits were the only ones to consistently show significantly higher MZ than DZ correlations for both twins in each pairwise combination. Given that liking for vegetables (and to a lesser extent fruits) are a primary focus of this thesis, in conjunction with the findings of the CT/CT and phenotypic correlations, it was decided that only vegetable preference, fruit preference and FF should be included in the multivariate covariance model-fitting analyses.

Table 8.2: Cross-twin cross-trait intraclass correlations and phenotypic correlations of food preferences

Food preference scales	Twin[b] and scale[a]	ICC[a] (95% Confidence Interval) MZ[c]	DZ[c]	Phenotypic correlation[d]
Vegetables & Fruit	Twin 1 V * Twin 2 F	**0.47** (0.39, 0.54)	**0.32** (0.26, 0.38)	**0.50**
	Twin 2 V * Twin 1 F	**0.53** (0.46, 0.59)	**0.31** (0.24, 0.37)	
Vegetables & Protein	Twin 1 V * Twin 2 P	**0.30** (0.21, 0.38)	**0.32** (0.26, 0.38)	**0.34**
	Twin 2 V * Twin 1 P	**0.32** (0.23, 0.40)	**0.27** (0.20, 0.33)	
Vegetables & Dairy	Twin 1 V * Twin 2 D	**0.21** (0.12, 0.30)	**0.21** (0.15, 0.28)	**0.26**
	Twin 2 V * Twin 1 D	**0.25** (0.16, 0.34)	**0.23** (0.16, 0.29)	
Vegetables & Snacks	Twin 1 V * Twin 2 S	**0.07** (0.03, 0.16)	**0.08** (0.01, 0.15)	**0.07**
	Twin 2 V * Twin 1 S	**0.19** (-0.07, 0.11)	**0.10** (0.03, 0.17)	
Fruit & Protein	Twin 1 F * Twin 2 P	**0.27** (0.18, 0.35)	**0.18** (0.12, 0.25)	**0.27**
	Twin 2 F * Twin 1 P	**0.22** (0.12, 0.31)	**0.21** (0.14, 0.27)	
Fruit & Dairy	Twin 1 F * Twin 2 D	**0.29** (0.20, 0.38)	**0.26** (0.19, 0.32)	**0.27**
	Twin 2 F * Twin 1 D	**0.23** (0.13, 0.31)	**0.23** (0.16, 0.29)	
Fruit & Snacks	Twin 1 F * Twin 2 S	**0.20** (0.10, 0.28)	**0.23** (0.16, 0.29)	**0.21**
	Twin 2 F * Twin 1 S	**0.18** (0.08, 0.27)	**0.17** (0.11, 0.24)	
Protein & Dairy	Twin 1 P * Twin 2 D	**0.28** (0.19, 0.37)	**0.24** (0.17, 0.30)	**0.27**
	Twin 2 P * Twin 1 D	**0.30** (0.21, 0.38)	**0.21** (0.14, 0.28)	
Protein & Snacks	Twin 1 P * Twin 2 S	**0.13** (0.03, 0.22)	**0.17** (0.10, 0.24)	**0.16**
	Twin 2 P * Twin 1 S	**0.11** (0.01, 0.20)	**0.18** (0.11, 0.24)	
Snacks & Dairy	Twin 1 S * Twin 2 D	**0.25** (0.16, 0.34)	**0.32** (0.26, 0.38)	**0.31**
	Twin 2 S * Twin 1 D	**0.23** (0.14, 0.32)	**0.31** (0.25, 0.37)	

[a] Abbreviations: Food preference Scales; V, Vegetables; F, Fruit; P, Protein; D, Dairy; S, Snacks. ICC, intraclass correlation.
[b] Randomly allocated twin (1 or 2) and scale used in the cross-twin cross-trait correlation.
[c] MZs, *n*=418-455 pairs; DZs, *n*=807-869 pairs.
[d] Pearson's product moment correlation coefficients; *n*=2478-2686. All correlations are significant at the 0.01 level (2-tailed).

Table 8.3: Cross-twin cross-trait intraclass correlations and phenotypic correlations of food preferences and food fussiness

Food preference and food fussiness scales	Twin[b] and scale[a]	ICC[a] (95% Confidence Interval) MZ[c]	DZ[c]	Phenotypic correlation[d]
Vegetables & Food Fussiness	Twin 1 V * Twin 2 FF	**-0.56** (-0.62, -0.49)	**-0.29** (-0.35, -0.22)	**-0.59**
	Twin 2 V * Twin 1 FF	**-0.56** (-0.62, -0.50)	**-0.33** (-0.39, -0.27)	
Fruit & Food Fussiness	Twin 1 F * Twin 2 FF	**-0.47** (-0.54, -0.40)	**-0.19** (-0.26, -0.13)	**-0.44**
	Twin 2 F * Twin 1 FF	**-0.44** (-0.51, -0.36)	**-0.19** (-0.26, -0.13)	
Protein & Food Fussiness	Twin 1 P * Twin 2 FF	**-0.34** (-0.42, -0.25)	**-0.19** (-0.26, -0.12)	**-0.41**
	Twin 2 P * Twin 1 FF	**-0.34** (-0.42, -0.26)	**-0.19** (-0.25, -0.12)	
Dairy & Food Fussiness	Twin 1 D * Twin 2 FF	**-0.33** (-0.41, -0.25)	**-0.13** (-0.20, -0.07)	**-0.32**
	Twin 2 D * Twin 1 FF	**-0.33** (-0.41, -0.24)	**-0.19** (-0.26, -0.13)	
Snacks & Food Fussiness	Twin 1 S * Twin 2 FF	**-0.01** (-0.10, 0.08)	**-0.10** (-0.16, -0.03)	**-0.09**
	Twin 2 S * Twin 1 FF	**-0.03** (-0.12, 0.06)	**-0.11** (-0.17, -0.41)	

[a] Abbreviations: Scales; V, Vegetables; F, Fruit; P, Protein; D, Dairy; S, Snacks, FF; Food Fussiness. ICC, intraclass correlation.
[b] Randomly allocated twin (1 or 2) and scale used in the cross-twin cross-trait correlation.
[c] MZs, *n*=418-455 pairs; DZs, *n*=807-869 pairs.
[d] Pearson's product moment correlation coefficients; *n*=2478-2686. All correlations are significant at the 0.01 level (2-tailed).

8.4.2. Multivariate model-fitting

Based on the findings of the twin correlations, it was decided that the multivariate model should include three traits; vegetable liking, fruit liking and food fussiness. This model provides information on both the common (multivariate) and the total (univariate) contributions of the genetic, shared environmental and unique environmental effects for each of these three traits.

8.4.2.1. Univariate estimates

The total ACE heritability estimates for food fussiness confirmed the results of the intraclass correlations. Food fussiness was found to be highly heritable (A=0.78, 95% CI; 0.73, 0.82) with the majority of the remaining variance in this trait explained by unique environment effects (E=0.17, CI; 0.15-0.20). The shared environment was found to have only a small effect on food fussiness (C=0.05, CI; 0.02-0.09).

The univariate ACE heritability estimates for the food preference traits were in keeping with those from the univariate analyses reported in Chapter 7. Univariate heritability for vegetables and fruit preferences were estimated at 49% and 57% respectively in the multivariate, compared to estimates of 50% and 57% in the previous univariate analyses. Similarly univariate estimates of shared environmental influences were more or less recovered in the multivariate model; 40% and 31% for vegetables and fruits compared to the estimates of 39% and 30% reported previously. The estimates of the total contribution of the unique environment to these food preference traits remained entirely consistent in the multivariate model (11% for vegetables and 13% for fruit in both).

See Figure 8.1 for an illustration of the multivariate model estimates of the total variance explained in each of the three traits by genetic, shared environmental and unique environmental influences (identified by straight, single-headed arrows).

8.4.2.2. Multivariate findings

8.4.2.2.1. Bivariate aetiological correlations

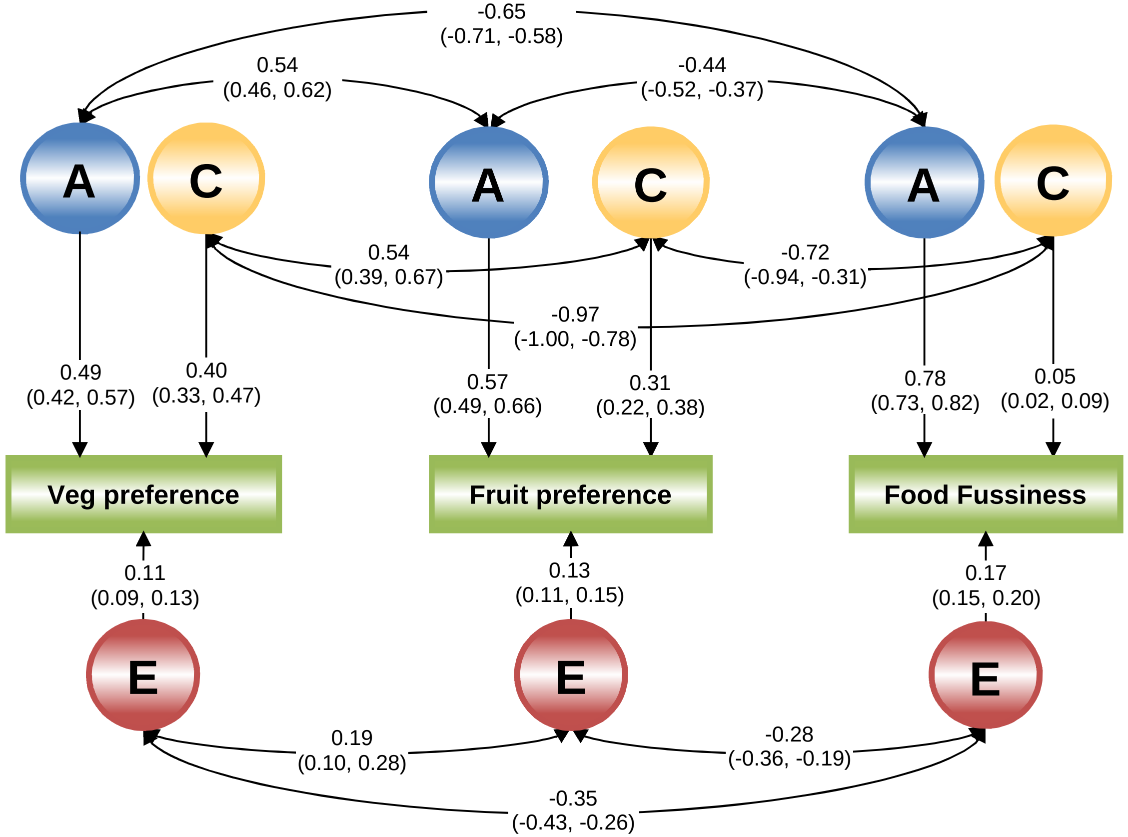
The Correlated Factors model provided estimates of the common genetic, common shared environmental and common unique environmental influences on vegetable liking, fruit liking and FF, as well as specific genetic, shared environmental and unique environmental influences on each of these traits. All of the parameter estimates for the full correlated factors model are shown in Figure 8.1. In order to aid interpretation, the phenotypic correlations derived from maximum-likelihood structural equation modelling, the bivariate heritability estimates, and the pairwise aetiological correlations are shown in Table 8.4.

The genetic correlations (r_g) between vegetable and fruit liking (0.54), liking for vegetables and food fussiness (-0.65) and liking for fruit and food fussiness (-0.44) were all significant and moderate to large, indicating many of the same genetic factors are shared between these traits. The negative genetic correlation for liking for vegetables and food fussiness was significantly stronger than the association between liking for fruit and food fussiness, showing that a particularly high proportion of the genetic influences driving food fussiness are also behind decreased liking for vegetables. The shared environment correlations (r_c) were also high for all three pairings of traits. Approximately half of the shared environmental influences on fruit and vegetable liking were common to these two traits (0.54), while almost three quarters of shared environmental influences on food fussiness and liking for fruit were shared (-0.72). The shared environmental correlation between liking for vegetables and food fussiness was the strongest with virtually all the shared environmental influences common to both traits (-0.97). The unique environmental correlations (r_e) were all smaller (0.19 to maximum -0.35) indicating fewer unique environmental effects are shared between these traits.

8.4.2.2.2. Bivariate ACE estimates

The bivariate heritability estimates indicated significant genetic contributions to the phenotypic associations between liking for vegetables and fruits, and food fussiness. The bivariate heritability estimates, which ranged from 58% for vegetable and fruit liking to 69% for vegetable liking and food fussiness and 70% for fruit liking and food fussiness (see Table 8.4), suggest the majority of the phenotypic correlation between each of these pairs of traits can be ascribed to common genetic factors. The remaining portions of the phenotypic correlations are primarily driven by common shared environmental factors (21 to 38%), with only a minimal contribution from common unique environmental influences (5 to 10%). This suggests there are a set of common genetic influences, as well as common shared environmental factors, that contribute significantly to the covariation between liking for vegetables, liking for fruits and food fussiness.

Figure 8.1: Full ACE correlated factors model showing the genetic and environmental influences on vegetable preference, fruit preference and food fussiness



Path diagram showing the genetic and environmental influences on fruit and vegetable preference and food fussiness for one child using a Correlated Factors Model. The rectangular boxes represent the measured phenotype (food preference or food fussiness). The circles indicate latent influences on the measured phenotype which include additive genetic effects (A), shared environmental effects (C) and unique environmental effects and error (E). The straight single-headed arrows show the causal paths, and the squared path coefficients on each causal path indicate the total variance explained in each trait by A, C and E. The curved double-headed arrows show the genetic, shared environment and unique environment correlations between the traits.

Table 8.4: Parameter estimates for covariance and common genetic, shared environmental and unique environmental effects underlying vegetable preference, fruit preference and food fussiness

FP and FF scales[a]	Phenotypic correlation[b] (95% CI)	Variance components for bivariate A, C and E[c] (as % of phenotypic correlation[d])			Aetiological correlation[e] (95% CI)		
		A	C	E	r_g	r_c	r_e
Vegetables*Fruit	0.49 (0.44, 0.55)	0.28 (58)	0.19 (38)	0.02 (5)	0.54 (0.46, 0.62)	0.54 (0.39, 0.67)	0.19 (0.10, 0.28)
Vegetables*FF	-0.59 (-0.64, -0.54)	0.40 (69)	0.14 (23)	0.05 (8)	-0.65 (-0.71, -0.58)	-0.97 (-1.0, -0.78)	-0.35 (-0.43, -0.26)
Fruit*FF	-0.42 (-0.47, -0.37)	0.29 (70)	0.09 (21)	0.04 (10)	-0.44 (-0.52, -0.37)	-0.72 (-0.94, -0.31)	-0.28 (-0.36, -0.19)

[a] Abbreviations: FP, food preferences; FF, food fussiness.

[b] Phenotypic correlation derived from structural equation modelling

[c] Proportion of variance in the phenotypic correlation that is explained by common additive genetic influences, common shared environmental and common non-shared environmental influences. The sum of the bivariate components equals the phenotypic correlation. All bivariate estimates were statistically significant

[d] The proportions of variance in the phenotypic correlations (accounted for by additive genetic effects, shared environment effects and non-shared environment effects) converted to percentages for ease of interpretation.

[e] r_g, genetic correlation; r_c, shared environmental correlation r_e, unique environmental correlation. A genetic, shared environmental or unique environmental correlation is significant if the 95% confidence interval does not include zero; all correlations in the model were statistically significant.

8.5. Discussion

8.5.1. Summary of findings

This study is the first to demonstrate that food fussiness is a highly heritable trait in young children. Furthermore, this novel investigation into the shared influences underlying preferences for vegetables and fruits, and food fussiness in childhood provides strong evidence for common genetic and environmental influences driving the observed phenotypic associations between these traits. There were two defined aims of this study and the findings are discussed below in the context of each question addressed.

8.5.1.1. The relative influences of genes and environment on food fussiness

The first aim of the present study was to obtain an estimate of the contribution of genetic and environmental influences to food fussiness in 3 year old children. The findings reveal food fussiness to be highly heritable (78%), with only a moderate influence of the environment driving this characteristic in young children. These results are similar to those from investigations of the closely related trait of neophobia; heritability estimates of 78% have been reported for neophobia in 8 to 11 year old children (Cooke et al., 2007) and more recently estimates of 72% heritability were found for this trait among 4-7 year olds (Faith et al., 2013).

Unique environmental influences (17%) were the second most important factor influencing variance in children's food fussiness in this sample, again a comparable finding to neophobia where unique environmental influences have been reported to account for between 22% and 28% of individual variance in children (Cooke et al., 2007; Faith et al., 2013). This suggests that despite sharing the same family environment, two siblings experience this environment differently which results in dissimilarities in this trait. The unique environmental influences causing sibling disparity in food fussiness may include a number of different factors. Children may respond to the same family environment or parental feeding practices differently because of what they themselves bring to the situation, meanwhile parents might treat their children differently, possibly in response to an individual child's needs or characteristics. Parent-child interactions are reciprocal so it is likely that fussier children display food avoidance tendencies which in turn cause parents to characterise their child as a picky eater and alter their feeding practices accordingly. There is evidence to suggest the techniques adopted by parents in response to food refusal, such as threatening to withhold treats (i.e. ‘if you don’t eat your vegetables you can’t have any pudding’) or offering food rewards (i.e. ‘if you eat your broccoli you can have some ice cream’) do not work and can even be counterproductive (Birch, Birch, Marlin, & Kramer, 1982; Newman & Taylor, 1992). Feeding interactions during mealtimes with a ‘fussy’ child are often extremely stressful for all involved which may result in increased resistance on the part of the child.

Unlike the findings from the neophobia studies, a small but significant influence of shared environmental effects was found for food fussiness (5%). These results could be interpreted as evidence that food fussiness, unlike neophobia, is at least partially determined by aspects of a child’s shared environment, or possibly, given the different ages of the children in the two studies, that the shared environment is a more important factor in both these traits at a younger age. However the disparity in findings regarding the aetiology of these two closely related constructs may simply be an artefact of the increased power to detect small effects offered by the multivariate model tested in the present study.

8.5.1.2. Are common genes or common environments behind the associations between food preferences and food fussiness in early childhood?

Both the CT/CT correlations and the covariance modelling suggested that covariation between vegetable preference, fruit preference and food fussiness are largely driven by common genetic influences, with the majority of the remaining covariation resulting from common shared environmental influences. Common influences of the unique child environment were the least important factor for explaining phenotypic covariation between these three traits.

The phenotypic correlations between the three traits were all considerable, but the negative association between liking for vegetables and food fussiness was particularly large (r=-0.59). Furthermore, shared genes appeared to play the strongest role in generating these phenotypic associations. Genetic influences were found to explain the majority of the phenotypic association observed between fussiness and each of the food preference traits (69% for vegetables and 70% for fruits), indicating that fussy children display lower preference for these foods primarily because these three traits are driven by the same underlying genetic factors. Additionally, the genetic correlation between vegetables and food fussiness was high (r_g=0.65), so any genes impacting on food fussiness are likely to also affect vegetable preference, and vice versa. The genetic correlation between fruit liking and food fussiness was slightly lower (r_g=0.44) suggesting a smaller though still considerable proportion of the genes influencing fruit preference influence food fussiness as well.

Together, these findings suggest that not only do liking for vegetables and fruits, and food fussiness co-vary strongly (particularly for food fussiness and vegetable preference), the largest proportion of this covariation is due to common genes and up to two thirds of the genetic effects on each trait are the same. This raises the question; what are the common genetic factors driving these associations? As discussed in Chapter 1, research on the topic of individual variation in human taste sensitivity has until recently focussed almost exclusively on genetically determined variation in taste sensitivity for phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP). PROP tasting, like fussiness and neophobia, may be related to food preferences. A number of studies have demonstrated decreased liking for fruits and vegetables among PROP tasters compared to non-tasters (Bell & Tepper, 2006; Drewnowski et al., 2000; Drewnowski et al., 1999; Kaminski et al., 2000; Keller et al., 2002), although findings are by no means unequivocal, and several studies, particularly those involving children, have reported no such link (Keller et al., 2002; Keller & Tepper, 2004; Lumeng, Cardinal, Sitto, & Kannan, 2008).

PROP sensitivity has been used as a marker for general taste ability and the most frequently applied test of taste function has involved asking people to rate this compound (Reed, 2008). It is possible that general heightened taste sensitivity could result in both a reluctance to taste unfamiliar foods and increased dislike and subsequent rejection of familiar foods. It is important to note that the food groups most associated with fussiness (fruits, vegetables, and to a lesser extent protein) in this thesis, and elsewhere to neophobia (Russell & Worsley, 2008), are also those for which preferences were found to be most heritable. No studies to date have demonstrated an association between increased PROP sensitivity and food fussiness (or neophobia), although one recent study found PROP sensitivity mediated the relationship between neophobia and soy food intake in Japanese preschoolers, such that high intake of soy foods was significantly associated with a low neophobia score in PROP tasters but not in non-tasters (Tsuji et al., 2012). Similarly in adults, only PROP tasters who were also ‘less food adventurous’ showed increased dislike for bitter or sharp-tasting foods (Ullrich, Touger-Decker, O'Sullivan-Maillet, & Tepper, 2004). Another study reported that PROP supertasters were familiar with fewer foods than mere tasters or non-tasters (Pasquet, Oberti, El Ati, & Hladik, 2002), but conversely

PROP tasters have not been found to describe themselves as “unadventurous” about food more often than non-tasters (Ullrich et al., 2004).

Recently it has been argued that PROP taster status is not the best predictor of general taste sensitivity or ability (Lim, Urban, & Green, 2008; Reed, 2008). A study comparing individual differences in perception of multiple taste stimuli found perception of PROP to be a weaker predictor of general taste sensitivity than perception of other stimuli such as sucrose or citric acid (Lim et al., 2008). These findings contradict the use of PROP as an indicator of general taste or oral perception and therefore dispute the assumption that the gene determined to account for variation in PROP tasting (TAS2R38) effects sensitivity to other tastes. A commentary on the use of PROP as a marker of taste sensitivity argues for a move away from defining supertasters by their response to this compound, instead focussing future research towards “general supertasters” who display heightened sensitivity to all or most stimuli (Reed, 2008). It seems likely that multiple taste phenotypes contribute simultaneously to preferences for foods and also towards eating behaviours such as fussiness or neophobia. Despite the earlier preoccupation with PROP, and the related gene TAS2R38, in relation to individual differences in taste perception and preference, research is now amassing on the contribution of other genes (Tepper et al., 2009) including; TAS2R43 and TAS2R44, which have been shown to relate to the bitter taste of saccharin (Pronin et al., 2007), and TAS2R16 and TAS2R38 which have been associated with behavioural responses to alcohol (Wang et al., 2007).

Common shared environmental factors were found to contribute to just under a quarter of the association between food fussiness and vegetable preference (23%) and food fussiness and fruit preference (21%) suggesting that some aspects of the shared environment jointly contribute to increased food fussiness and decreased preference for fruits and vegetables. The aetiological correlation for the shared environment reveals that almost all of the shared environmental influences that contribute to food fussiness also contribute to vegetable preference (r_c=0.97), while almost three quarters of these influences are shared between food fussiness and fruit preference (r_c=0.72). These correlations may seem unfeasibly high, but they are perhaps less surprising when considered in the context of the overall shared environmental influence on food fussiness which is relatively low (5%) meaning, while almost all of the shared environmental influences on food fussiness are shared with those for vegetables preference, this is in fact only a high proportion of a relatively small contribution.

The phenotypic covariation between vegetable and fruit preferences was also largely explained by common genetic factors (58%), although common shared environmental influences also contributed considerably (38%). This suggests children who like vegetables, also like fruit because of common genetic influences contributing to both characteristics, but also because many of the aspects of the shared environment that influence vegetable preference also influences fruit preference. Moreover, the aetiological r_g and r_c correlations were also high for fruit and vegetable preference (both 0.54) indicating that a considerable proportion of the genes, and of the shared environment factors that influence preference for one of these foods also influences the other. Common shared environmental influences affecting preferences for both fruits and vegetables likely include aspects of the early family feeding environment. Siblings raised in the same household at the same time will share very similar diets and experience many of the same food exposures. Other shared environmental factors such as availability and parental modelling are also likely to contribute to commonalities in children's preferences for these foods. Indeed, maternal fruit and vegetable intake was identified as a predictor for both fruit and vegetable preference in Chapter 6 of this thesis.

There was a small but significant role for common influences of the unique environment in the relationship between vegetable preference, fruit preference and food fussiness. Common unique environmental influences only explained between 5% and 10% of the phenotypic correlations between these traits. However, the aetiological correlations revealed that many of the unique environmental influences were common to vegetable preference and food fussiness (r_e=0.35), while marginally fewer were shared between fruit preference and food fussiness (r_e=0.28) and fruit and vegetable preference (r_e=0.19). The common unique environment captures covariation across the traits for each twin driven by unique life experiences that are not shared with their co-twin. These could include variation in parental feeding practices, food exposures, or aversions resulting from post-ingestive illness or disturbance.

The finding that a considerable proportion of the variance in preferences for fruits and vegetables, and in food fussiness was independent of the other traits suggests there are unique genetic and environmental factors contributing to each of the traits which remain unrelated to the others. This unique variance may reflect distinct mechanisms unique to each trait but it is also possible that fruit preference, vegetable preference and food fussiness are uniquely related to additional behavioural or psychological traits, which are themselves influenced by both genetic and environmental influences, such as other appetitive or personality traits. Previous research has shown individuals who are naturally more sensation seeking tend to be much less food neophobic (Galloway et al., 2003; Pliner & Melo, 1997) possibly because they have lower general neophobia in all domains (Pliner & Hobden, 1992). Other personality factors, such as anxiety (Galloway et al., 2003), neuroticism (Steptoe, Pollard, & Wardle, 1995) and openness (McCrae et al., 2002), have also been shown to relate to food neophobia. Conceivably, given that food neophobia is likely a part (though not all) of a fussy eater's profile, similar associations might be expected for food fussiness. Additionally, a recent study suggested children characterised as fussy eaters may also display 'tactile or oral defensiveness' (Smith, Roux, Naidoo, & Venter, 2005). This is type of sensory sensitivity characterised by an avoidance of activities that involve oral touch, such as tooth brushing but also an aversion of certain textures of food resulting in food selectivity. Food fussiness and sensory sensitivity are both common in children with autism spectrum disorders and oral defensiveness has been highlighted as a key mechanism for explaining this association (Cermak, Curtin, & Bandini, 2010). While there has been some suggestion of a link between oral defensiveness and problems with eating vegetables (Smith et al., 2005), this trait may be largely unrelated to fruit preference. It is also likely that genetic and environmental influences on preferences for sweet foods relate to preferences for fruit but not to the other traits measured in this study.

8.5.2. Limitations

This was the first study to explore the extent to which common genes or environmental influences drive phenotypic associations between food preferences and food fussiness. The large sample size and multivariate design provides robust estimates for both the univariate model of heritability for food fussiness and also for the shared pathways influencing food fussiness and preferences for vegetables and fruits. However there are several limitations that should be acknowledged. The problems associated with using parent-reported measures of food preferences and the various criticisms of the twin design have already been discussed in detail in this thesis (see Chapter 6 and Chapter 7), and similarly apply to the present study. Moreover, this study was cross-sectional and limited to 3 year old children. Given food fussiness increases over early childhood (as demonstrated in Study 2) and likely peaks in the preschool years, the findings of this study may reflect a very specific period in development, limiting the wider implications of these results. There is a need for a replication of this research across broader age ranges.

To date, studies of food fussiness have been hindered by the lack of a standard measure for this trait (Dovey et al., 2008). The CEBQ measure of food fussiness used in this research is superior to some of the others implemented previously, in that it is an internally reliable scale comprising six items, as opposed to a single item asking if a parent considers their child a picky eater (Carruth et al., 2004). It also attempts to address the conceptual overlap between fussiness and neophobia, by including items that address both neophobic and picky traits. Although arguably this could add to the confusion in distinguishing between the two related behaviours (Dovey et al., 2008). This measure of fussiness would benefit from external validation as unlike other CEBQ scales (including; satiety responsiveness, food responsiveness and enjoyment of food), food fussiness has not been validated using behavioural measures in children (Carnell & Wardle, 2007).

8.5.3. Conclusions

These findings confirm what many parents already know, that children's refusal to eat certain foods is not simply the product of impoverished early feeding environments or poor parental feeding practices. High heritability of food fussiness demonstrates that these eating behaviour patterns are at least partially determined by genes not the environment. However, notwithstanding the large genetic contribution to food fussiness, research has consistently shown that refusal of new foods (neophobia) and/or a variety of familiar and unfamiliar foods (fussiness) can be modified through exposure-based interventions. Exposure leads to novel or rejected foods becoming more familiar, resulting in increased acceptance (Cooke, 2007), but that is not to say that exposure techniques may not be more arduous to implement, or success more difficult to achieve, with children who are extremely fussy. Additionally the unique child environment contributed to individual variation in fussiness illustrating the need to identify the sources of these unique environmental effects, both within and outside the home environment. In order to do this it is necessary to explore food environments at the level of the child, rather than the family (Plomin et al., 2008).

Two important principals to consider when studying genetic variation on complex traits are; pleiotropy, which occurs when one gene influences multiple phenotypic traits, and polygenicity, whereby multiple genes converge resulting in a single phenotype (Plomin et al., 2008). Genetic correlations can be caused by pleiotropy and complex traits are also likely to be polygenic (influenced by many genes). It is likely that food preferences and food fussiness are highly polygenic with countless genes each contributing a small amount to the genetic variation in these phenotypes. This makes it difficult to identify specific genes responsible for food preferences and/or food fussiness. However, that does not mean these findings do not have potential implications for molecular genetic research. Progress has been made in identifying genetic influences on other complex polygentic traits. For example, a fat mass and obesity-associated gene (FTO) has been found to correlate with obesity and FTO was a found to explain 0.5% of the variance in BMI (Frayling et al., 2007). The genetic correlations between the food preference and food fussiness traits in this study were considerable, indicating that if genes that contributed, even minimally, to variation in fussiness were identified then they would also be likely to influence preferences for vegetables and fruits. These findings provide support for the search for 'generalist genes' relating to heightened sensitivity to all or most taste stimuli. However, it should be acknowledged that the aetiological correlations were not comprehensive, showing that there is also substantial genetic heterogeneity in the three traits. The wider search for genes underlying food preferences would therefore benefit from measuring the many dimensions that characterise taste sensitivity, oral sensitivity and food rejection in order to obtain a complete picture.

In conclusion, this study demonstrates that not only is food fussiness a highly heritable trait in young children, common genes are driving the association between children's fussiness and decreased preferences for certain foods, particularly vegetables. These findings highlight the need to take a therapeutic approach to food rejection, by targeting interventions for increasing vegetable acceptance at the individual level, and utilising established repeated exposure techniques, parents could potentially succeed in modifying their children's preference for these commonly rejected foods.

CHAPTER 9 . STUDY 5: 'TINY TASTES' - AN INTERVENTION TO INCREASE VEGETABLE ACCEPTANCE IN YOUNG CHILDREN[15]

9.1. Background

As discussed in Chapter 1, patterns of food refusal, including fussiness and neophobia, often begin around the age of two years, and although widespread among preschool children (Birch, 1999; Dovey et al., 2008; Pelchat & Pliner, 1995), are nonetheless a significant cause of anxiety to parents and a common reason for consulting health professionals. Family mealtimes with fussy children can become a source of stress which in turn may negatively affect children's eating behaviour. Fussy eating is associated with decreased preferences for all foods but specifically fruits and vegetables, as illustrated by the findings reported in Chapter 6.

Vegetables are commonly among children's least liked foods (see findings from Chapter 5) and heritability analyses of vegetable preference (reported in Chapter 7) suggest the home environment, may contribute to shaping preference for these commonly disliked foods in early childhood. Aspects of the early food environment, including access, availability and parental modelling are all likely to contribute to children's unique patterns of food preferences. However, study 4 (Chapter 8) highlighted that aspects of the individual, such as the highly heritable trait of food fussiness, are strongly linked to children's dislike for certain foods especially vegetables. These findings indicate that once negative preferences for certain foods are established, interventions targeting food rejection directly, and at the individual level, might be more successful than interventions targeted at the environmental level (e.g. simply increasing fruit or vegetable availability). Several previous studies have demonstrated that daily taste exposure can increase children's acceptance of unfamiliar or disliked foods (Birch, 1987; Wardle, Cooke, et al., 2003; Wardle, Herrera, et al., 2003). This involves offering the child a small quantity of the target food, usually outside of mealtimes, and encouraging them to taste it in a non-pressured environment on repeated occasions (e.g. daily) up to a maximum of 14 times. Furthermore, the addition of small rewards for tasting as part of the exposure protocol appears to have no adverse effect on the outcome and can help encourage the pickier children to

---

[15] A version of this chapter has been published online ahead of print: Fildes, A., van Jaarsveld, C. H. M., Wardle, J., & Cooke, L. (2013). Parent-Administered Exposure to Increase Children's Vegetable Acceptance: A Randomized Controlled Trial. *Journal of the Academy of Nutrition and Dietetics*.

comply (see Chapter 2 for a longer discussion of the use of rewards in interventions) (Cooke, Chambers, Anez, Croker, et al., 2011; Cooke, Chambers, Anez, & Wardle, 2011). A study in which parents were given brief training in the exposure protocol at a home visit, was successful in increasing children's acceptance of vegetables and parents were extremely positive about the programme (Remington et al., 2012).

However the nature of this previous intervention involved significant input from researchers which is both economically and practically prohibitive of dissemination on a wider scale. Given the positive feedback from parents in this earlier study, and the relative ease with which parents managed to carry out the exposure procedure, it may be that simply mailing instructions and materials to parents without any researcher input might hold promise as a cost-effective and easily disseminable intervention.

9.2. Study aims

The aim of the present study was therefore to evaluate the efficacy of a taste exposure plus reward intervention to increase preschool children's acceptance of vegetables, delivered through mailed materials and access to an online video.

9.3. Methods

9.3.1. Study design

Using a double pre-test, randomised controlled design, we compared a protocol of parent-administered taste exposure sessions with a no-treatment control condition. Outcomes (intake and liking of the target vegetable) were assessed through parent-administered tests at baseline (test 1), 14 days later, immediately before the intervention period (test 2), and 14 days after that, immediately following the intervention period (test 3). This design permitted between group analyses of the treatment effect (test 3 controlling for test 2), as well as within-group comparisons of change over the rest-phase (test 1- test 2) versus experimental-phase (test 2- test 3).

9.3.2. Sample and methods

9.3.2.1 Recruitment and study group allocation

Participants were families with young twins taking part in the Gemini cohort study. All active Gemini families (n=2321) were sent a questionnaire when their children were 3 years old (T5, described fully in Chapter 4) which included an invitation to take part in the ‘Tiny Tastes’ study to test a method of increasing children’s acceptance of vegetables. Just under half (n=1006; 43%) of the families approached expressed interest in the study.

Randomisation was at the level of the family stratified by twin zygosity (monozygotic and dizygotic) with 503 families allocated to each of the conditions. An amendment to the full Gemini Ethical approval was obtained for this study and approval was granted by the Joint UCL/UCLH Committees on the Ethics of Human Research.

9.3.2.2 Study procedure

Families were sent instructions for assessing intake and liking at test 1, test 2 and test 3, record sheets for the results, a link to a demonstration video for the assessment procedure, and a study calendar to remind them when to carry out the three tests (copies of the study materials are provided in Appendix 3). Parents were asked to select a ‘target’ vegetable that neither twin liked. They were given some suggestions of vegetables that are easily available and edible without cooking, these were; carrot, cucumber, celery, sugar snap peas, red pepper and cabbage. Parents could select other vegetables if these were not suitable or were all already liked by one or both their twins. Parents in the intervention group also received a sealed envelope containing the ‘Tiny Tastes’ instruction leaflet, a link to an online demonstration video, progress charts, and stickers as rewards for tasting (still images from the demonstration video are shown in Figure 9.1). They were asked to open the pack after they had completed test 2.

Completed record sheets were returned for 472 children (216 in the intervention group and 256 in the control group). Of the 770 non-participating families, 84 formally withdrew (17 said their children had no issues with eating vegetables, 38 had other priorities, and 29 gave no reason). The remaining 686 families failed to respond but did not formally withdraw from the study.

Figure 9.1: Still images from the 'Tiny Tastes' instruction video

9.3.2.2.1. Intervention

The ‘Tiny Tastes’ instructions asked parents to offer the intervention children a very small piece of their target vegetable every day for 14 days, allowing the child to choose a sticker as a reward if they tried it. Parents were asked to do this separately with each twin and outside of a meal time. The process was described to the child as ‘playing the tasting game’. Parents were asked to ensure the child understood that the sticker was a reward for tasting the target vegetable. They were encouraged to record on a progress chart whether the daily taste session took place and whether the child tried the vegetable. The instructions stressed the importance of repeated exposure, explained the techniques of exposure feeding, and emphasised the need for patience and persistence. Parents were also directed to a website with an online video demonstrating the intervention procedure being carried out by a researcher.

Families assigned to the control group were not sent the ‘Tiny Tastes’ instructions during the study period and did not perform the daily tastings, but they were told they would receive information about a technique to help their child to like vegetables after they had completed the 3 tests and returned their record sheets.

9.3.2.2.2. Outcome measures

The primary outcomes, intake and liking, were assessed at three taste test sessions (test 1, test 2 and test 3), with each twin tested separately. Parents were instructed to cut six approximately equal-sized pieces of the target vegetable (approximately the size of a five pence coin) and invite the child to eat as many as they liked. No reward was offered at the test sessions. If the child finished all six pieces, parents cut more and continued until the child had eaten as much as they wanted. Parents were asked not to encourage their child to eat and to respond neutrally if they refused. Parents recorded the number of pieces of vegetable the child ate and this constituted the intake data. Parents were also asked to estimate how much the child liked the target vegetable using a 9 point scale anchored with ‘dislikes a lot’ and ‘likes a lot’; which was scored 1-9 for quantitative analyses. Parent ratings were used because of the children’s young age.

Parents in the intervention condition were sent a follow-up questionnaire in which they were asked to what extent they agreed with the following statements: ‘I think the tasting game worked to make my twins more willing to try vegetables’, ‘I would play the tasting game with my children again in the future’ and ‘I would recommend the tasting game to a friend’, with response options of ‘strongly disagree’, ‘disagree’, ‘neither agree nor disagree', 'agree' and 'strongly agree'. They were also asked how easy they found it to follow the information in the pack and how easy they found it to complete the procedure (very easy, easy, neither easy nor difficult, difficult and very difficult). Finally, they were invited to give any comments on the 'Tiny Tastes' procedure and materials.

9.3.3. Statistical analyses

9.3.3.1. Ordinal regression

Because the distributions of intake and liking were skewed, responses were grouped into three categories to optimise use of the variation in the data for the primary analyses. For intake, the groups were: non-eaters (0 pieces), low-eaters (1–2 pieces) and eaters (3 or more pieces). For liking, the groups were: dislike (1-3), neither like nor dislike (4-6) and like (7-9). An ordinal regression was used to examine group differences at test 3 (intake or liking) with the respective test 2 intake or liking score acting as a covariate. The analyses were repeated using alternative cut-off criteria to group the data (i.e. increasing the threshold for categorising eaters) but the results remained the same.

An ordinal regression is an extension of logistic regression and is based on a model called the 'proportional odds model'. This model turns the ordinal scale into multiple binary cut-off points and the number of cut-offs is always one less than the number of categories (which is 2 in this case). These cut-off points can be thought of as thresholds that need to be crossed when going from one category to the next i.e. in the context of the ordinal 'intake' variable the thresholds would be; from category 1 (non-eaters) to category 2 (low-eaters) and from category 2 (low-eaters) to category 3 (eaters). What is then estimated is the probability of observing a particular category or lower (Norušis, 2012).

When conducting an ordinal regression it is important to test the assumption of parallel lines. Ordinal regression assumes that the relationships between the independent variables and the logits (the odds that an event occurs) are equal across the three outcome categories, this assumption of parallel lines was met for all ordinal regression analyses in this study (p>0.05).

Standard commands in statistical software typically treat data as simple random samples; however the data used in this study were from twin children who are necessarily clustered within families. A potential consequence of this could be an underestimation of standard error. Therefore, complex sampling techniques (SPSS version 20) were used in all ordinal regression models to take account of the clustering of twins within families (Snijders & Bosker, 2012). In order to confirm the complex samples technique effectively controlled for the clustering of twins, analyses were also repeated randomly selecting one twin per family and results remained the same. Data analyses used SPSS software (version 20; SPSS Inc).

9.3.3.2. Secondary analyses

Unlike the distributions of the continuous intake and liking variables, the intake and liking change scores were normally distributed and met assumptions for parametric testing. The secondary analyses compared change in intake and liking utilising the full range of scores between the rest-phase (test 1 to test 2) and the experimental-phase (test 2 to test 3), using repeated measures ANOVAs. When a significant time by group interaction was detected, paired samples t-tests were conducted separately for each group. Differences in change scores between groups were tested using independent samples t-tests. These were defined as secondary analyses because calculated change scores may be biased due to regression to the mean (Vickers & Altman, 2001).

9.3.3.3. Power

Power calculations for between group analyses of intake change scores were calculated using G-Power (version 3.1.7). Power calculations were based on results from the previous home-based vegetable exposure study (Remington et al., 2012) where the mean difference in post-intervention vegetable intake between the sticker reward and control groups equated to a medium effect size (mean difference = 1.27; 95% CI: 0.47, 2.01; Cohen's d = 0.72). The power calculations indicated that 90 participants per group would provide 90% power to detect the previously reported effect size of the intervention condition compared with a no-treatment control.

9.4. Results

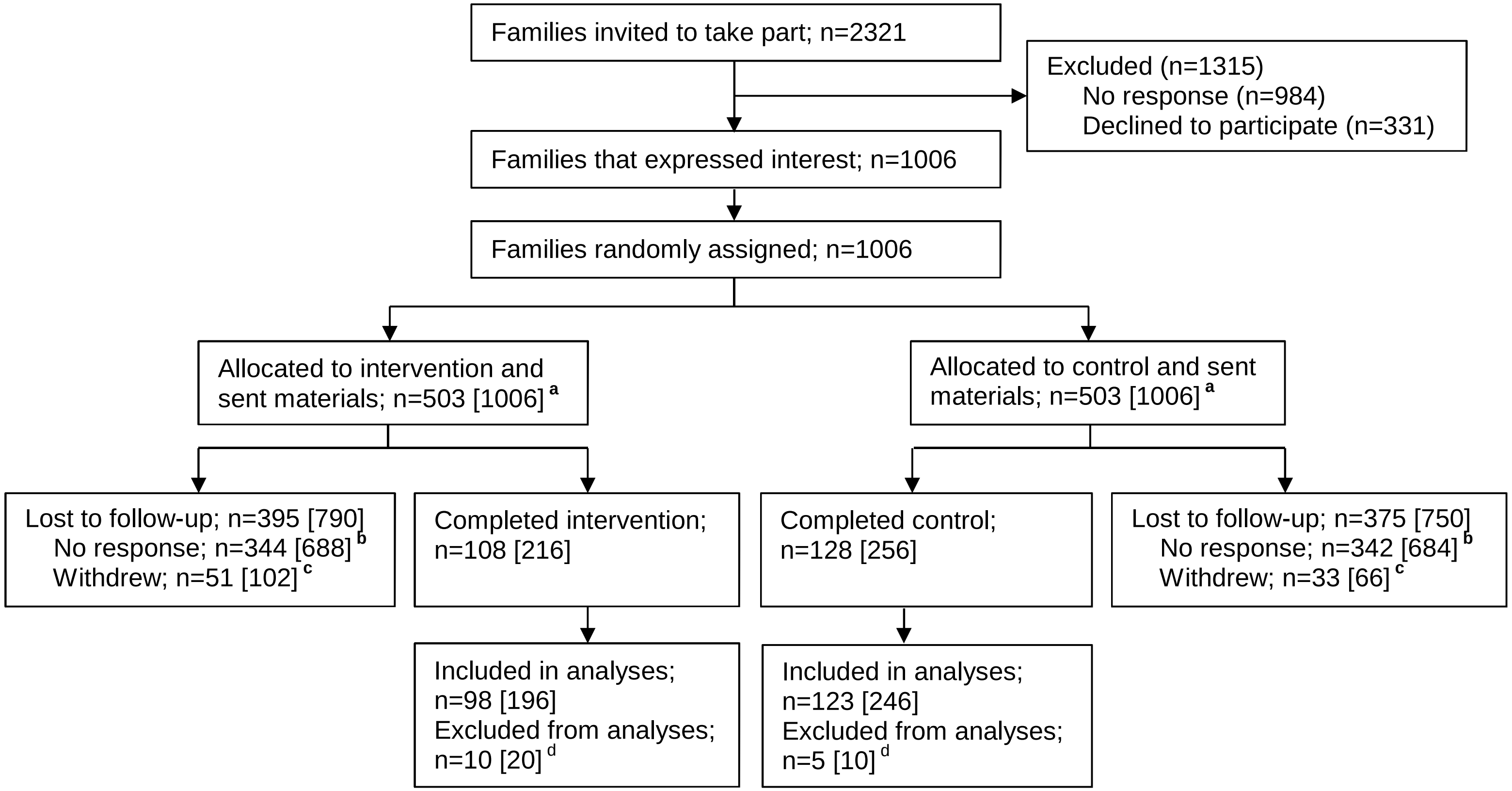
9.4.1. Summary statistics

Of 472 test sheets returned, 30 (20 intervention, 10 control) were not correctly completed and were therefore excluded from the analyses. A total of 442 children, 196 in the intervention group and 246 in the control group were included in the analyses. The flow of families participating throughout the trial is shown in Figure 9.2, and sample characteristics are summarised in Table 9.1 Approximately half of the children in each group were male (intervention; 51%, control 50%) which is comparable to the full Gemini cohort. Approximately half the mothers' (51%) were educated to a minimum of undergraduate level which is higher than for the full cohort (42%: χ^2=6.29, p=0.012) and maternal BMI in this sample was lower compared to the full cohort (24.0 versus 25.1: $t(2612)=3.14$, p=0.001). There were no group differences in the intervals (days) between the 3 tests (see Table 9.1), but children in the Intervention group had significantly lower intake and liking than the control group at test 1 and test 2 (see Table 9.2).

Table 9.1: Demographics, target vegetable distribution and test intervals

	Intervention (n=196)	**Control** (n=246)
Maternal age (years) (mean, sd)	38.0 (4.8)	37.3 (4.8)
Maternal education (n, %)		
Below university level	96 (49.0)	120 (48.8)
University level or above	100 (51.0)	126 (51.2)
Maternal BMI (mean, sd)	24.2 (4.2)	24.0 (4.0)
Child age (years) (mean, sd)	3.9 (0.3)	3.8 (0.3)
Child sex (n, %)		
Male	100 (51.0)	123 (50.0)
Female	96 (49.0)	123 (50.0)
Target vegetable (n, %)		
Red pepper	66 (33.7)	62 (25.2)
Celery	40 (20.4)	74 (30.1)
Cucumber	32 (16.3)	34 (13.8)
Carrot	22 (11.2)	28 (11.4)
Sugar snap peas	12 (6.1)	20 (8.1)
Cabbage	6 (3.1)	18 (7.3)
Other	18 (9.2)	10 (4.1)
Test intervals (days) (mean, sd)		
Interval between test 1 and test 2	17.8 (6.7)	17.0 (5.8)
Interval between test 2 and test 3	18.7 (9.4)	17.1 (9.2)

Figure 9.2: Flow of participants through the 'Tiny Tastes' trial



[a] n=numbers of families. Numbers of children are provided in square brackets
[b] Did not return test sheets
[c] Withdrew due to the children having no issues with eating vegetables, other priorities or failed to provide a reason
[d] Test sheets were completed incorrectly resulting in exclusion from the analyses

Table 9.2: Group differences in intake and liking at baseline (test 1), immediately before the intervention (test 2) and immediately following the intervention (test 3)

	Intervention n (%)[a]	Control n (%)	OR	95% CI (*p* value)
Intake				
test 1			0.67[b]	0.51–0.87 (0.003)
Non-eaters	97 (49.5)	101 (41.1)		
Low-eaters	60 (30.6)	72 (29.3)		
Eaters	39 (19.9)	73 (29.7)		
test 2			0.69[b]	0.53–0.90 (0.007)
Non-eaters	88 (44.9)	93 (37.8)		
Low-eaters	60 (30.6)	68 (27.6)		
Eaters	48 (24.5)	85 (34.6)		
test 3			12.05[c]	8.05–18.03 (<0.001)
Non-eaters	18 (9.2)	96 (39.0)		
Low-eaters	37 (18.9)	56 (22.8)		
Eaters	141 (71.9)	94 (38.2)		
Liking				
test 1			0.62[b]	0.46–0.85 (0.003)
Dislike	136 (69.4)	147 (59.8)		
Neither like nor dislike	37 (18.9)	48 (19.5)		
Like	23 (11.7)	51 (20.7)		
test 2			0.69[b]	0.51–0.94 (0.019)
Dislike	120 (61.2)	134 (54.5)		
Neither like nor dislike	47 (24.0)	51 (20.7)		
Like	29 (14.8)	61 (24.8)		
test 3			12.34[c]	7.97–19.12 (<0.001)
Dislike	25 (12.8)	118 (48.0)		
Neither like nor dislike	59 (30.1)	61 (24.8)		
Like	112 (57.1)	67 (27.2)		

[a] Total n=442
[b] Ordinal regression analyses using complex samples taking into account clustering of twins in families.
[c] Ordinal regression analyses adjusted for Test 2 using complex samples taking into account clustering of twins in families.

9.4.2. Primary analysis

In the control group, the percentage of children who ate none of the target vegetable was relatively constant throughout the study period; test 1 (41%), test 2 (38%) and test 3 (39%). In the intervention group, the percentage of non-eaters was constant from test 1 (50%) to test 2 (45%), but dropped to 9% after the intervention period (test 3) (see Table 9.2). Intervention participants had higher odds of eating more of the target vegetable (OR=12.05, 95% CI 8.05–18.03, $p<0.001$) and liking the target vegetable more (OR=12.34, 7.97–19.12, $p<0.001$) over the intervention period. Changes in intake and liking over the experimental-phase (test 2- test 3) are shown in Figure 9.3 and

Figure 9.4, which illustrate the large increase in percentage of children classified as 'eaters' and 'likers' in the intervention group.

9.4.3. Secondary analysis

Changes in intake across the two study phases using continuous data are shown in Figure 9.5. Both groups increased intake of the target vegetable slightly during the rest-phase (p=0.01), but there was no significant time by group interaction (p=0.43) indicating rest-phase change in intake did not differ between groups. Comparisons of change in intake over the rest-phase compared to the experimental-phase revealed a significant time by group interaction (p<0.001). Change in intake did not differ significantly between the two phases for the control group (rest-phase: mean change=0.60, SD=3.90, experimental-phase: mean change=0.61, SD=4.35, paired t-test; t=0.04, p=0.97). In contrast, change in intake differed significantly between the two phases for the intervention group (rest-phase: mean change=0.32, SD=3.36, experimental-phase: mean change=4.07, SD=7.52, paired t-test; t=6.03, p<0.001).

Similar results were obtained for liking (see Figure 9.6). An overall increase in liking of the target vegetable was observed during the rest-phase (p<0.01), but there was no significant time by group interaction (p=0.50). A significant time by group interaction was found for rest-phase liking change scores compared to experimental-phase liking change scores (p<0.001). Changes in the control group's liking did not differ across the two phases (rest-phase: mean change=0.27, SD=1.89, experimental-phase: mean change=0.31, SD=1.36, paired t-test; t=0.24, p=0.81) but was large and highly significant for the intervention group (rest-phase: mean change=0.39, SD=1.61, experimental-phase: mean change= 2.81, SD=2.50, paired t-test; t=9.94, p<0.001).

Figure 9.3: Intake category distribution (%) by group at test 2 and test 3

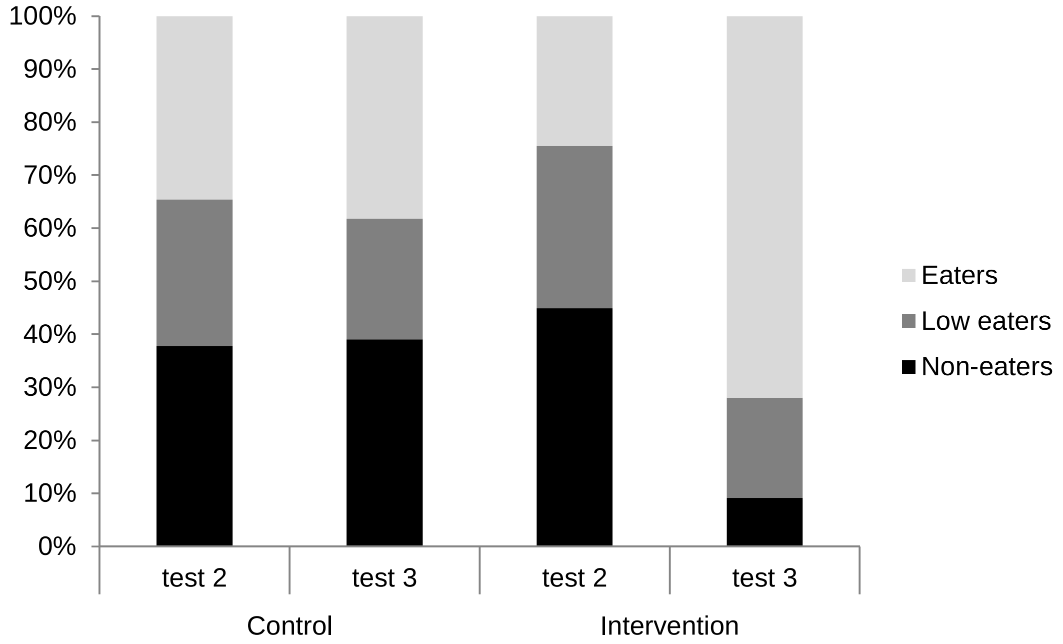


Figure 9.4: Liking category distribution (%) by group at test 2 and test 3

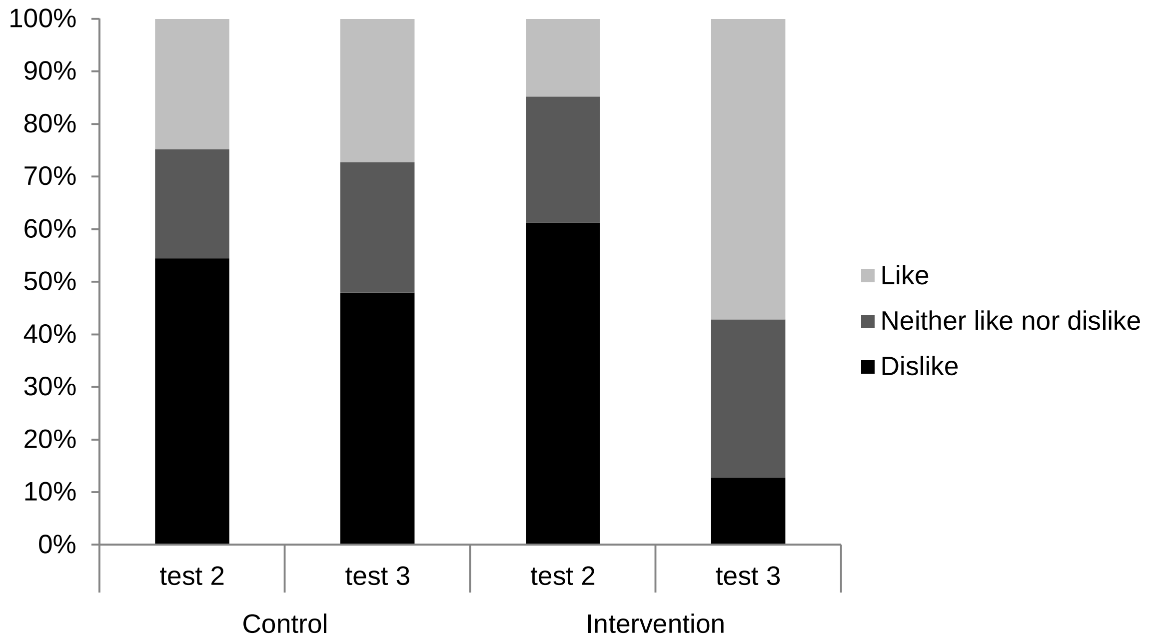


Figure 9.5: Mean (±SEM) intakes of the target vegetables in intervention and control group based on continuous data [a]

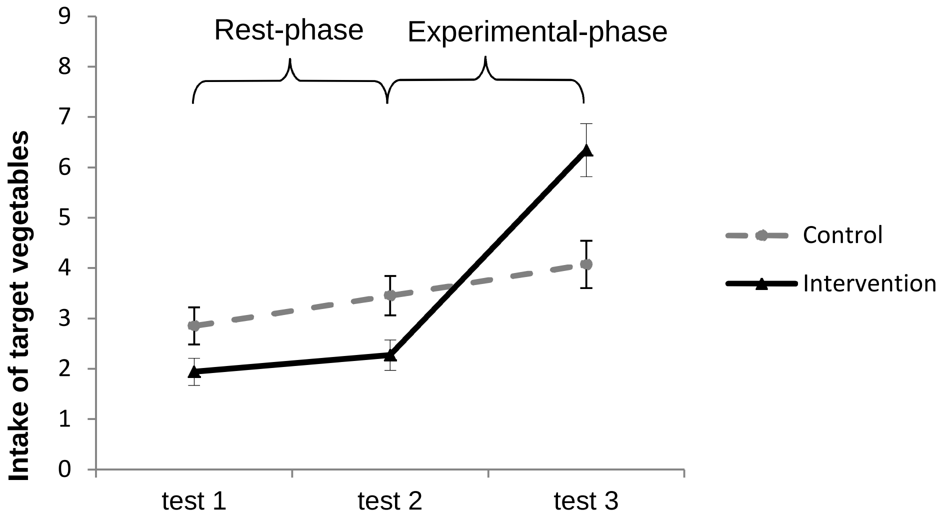
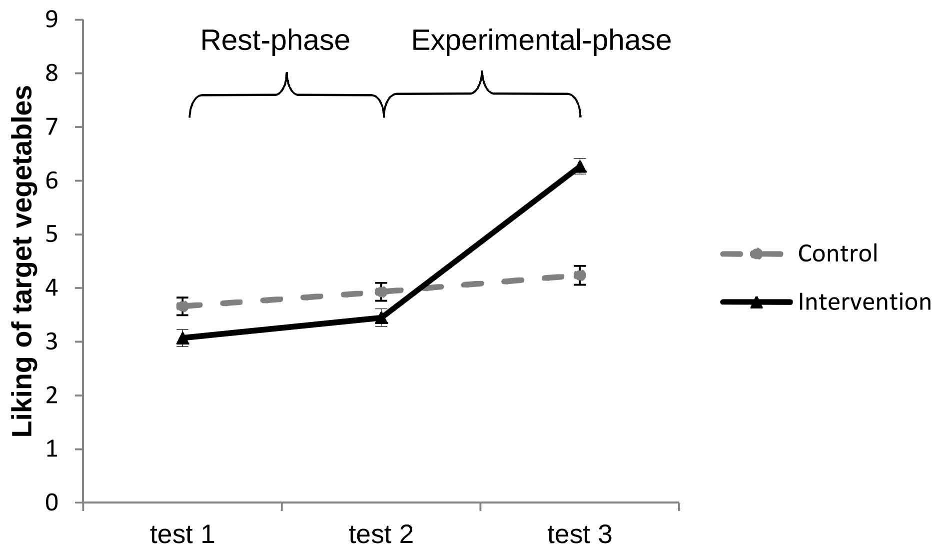


Figure 9.6: Mean (±SEM) liking of the target vegetables in intervention and control group based on continuous data[b]



Intake (or liking) change scores were calculated using the full range of scores.

[a] During the rest-phase, intake change scores did not differ between groups (intervention; mean change=0.32, SD=3.36, control; mean change=0.60, SD=3.90, t-test; t= -0.80, p=0.43). During the experimental-phase the intervention group had significantly higher intake change scores (intervention; mean change=4.07, SD=7.52, control; mean change=0.61, SD=4.35, t-test; t=6.06, p<0.001) than the control group.

[b] Similarly, during the rest-phase, liking change scores did not differ between groups (intervention; mean change=0.39, SD=1.61, control; mean change=0.27, SD=1.89, t-test; t=0.68, p=0.49). During the experimental-phase the intervention group had significantly higher liking change scores (intervention; mean change=2.81, SD=2.50, control; mean change=0.31, SD=1.36, t-test; t=13.41, p<0.001) than the control group.

9.4.4. Exposure protocol compliance, acceptability and parental feedback

Intervention group parents were asked to return the progress charts recording the daily tastings during the experimental-phase. Among the 175 returned (89% of the intervention children), the mean number of exposure occasions was 13.8 (range 11-14), and children tasted their target vegetables a mean of 12.4 times (range 0-14). Children complied with the intervention by trying their target vegetable on an average of 90% (range 0-100%) of the exposure occasions during the experimental-phase.

The follow-up questionnaire was completed by 87 (89%) of intervention families. The majority of parents (80%) agreed (or strongly agreed) that the procedure made their twins more willing to try vegetables. Most (85%) agreed that they would use it again, and 87% agreed that they would recommend it to a friend. In addition, 94% of parents agreed that the information was easy to understand, and 75% described completing the procedure as ‘easy’ or ‘very easy’, with a further 20% of families describing it as ‘neither easy or difficult’. While only 15 parents reported having viewed the online video, all but one reported finding it helpful.

In the comments about participating in the study, parents were entirely positive. The following comments were typical: *“Absolutely amazing – they didn’t even like the smell of celery before this and now they can’t get enough of it!”* and *“My very picky son (who has a twin sister who will try anything) will now ask for cucumber and is more than happy to eat a meal with pasta which beforehand he would not even have on his plate. I would thoroughly recommend the tasting game to anyone. Overall, I am amazed at how such a simple idea can work so well!”*

9.5. Discussion

9.5.1. Summary of findings

The results of this study demonstrate that an intervention comprising parent-delivered taste exposure, coupled with rewards can increase acceptance of a disliked vegetable without any health professional involvement. Using simple mailed instructions alongside a link to a video demonstration, parents were able to carry out the specified 14 exposure sessions with sticker rewards, resulting in children increasing their liking and intake of the target vegetable. Qualitative feedback about the programme was also extremely positive.

There were some differences in the results compared with a previous researcher-delivered intervention; the number of children declining any of the target food at the pre-test was slightly higher (over 40%) in this sample compared with the sample tested by a researcher in a classroom (31%) (Cooke, Chambers, Anez, Croker, et al., 2011). This may reflect the ‘stranger effect’; a common finding of lower compliance with instructions from parents than from an unfamiliar person (McCoy & Zigler, 1965; Stevenson, Keen, & Knights, 1963). However, refusal in the intervention group dropped to 10% after the rewarded tastings occasions compared with little change in the control group. In terms of increases in intake, the results were similar to those obtained with a researcher-delivered intervention.

It is not possible to assess the optimal number of vegetable exposures required to modify children’s vegetable acceptance from the present findings. The 14 exposure sessions suggested in the present study were based on previous research which has demonstrated 10-12 exposures to be sufficient for increasing acceptance. The recommendation of fourteen exposures also allowed for missed exposure sessions and fitted the natural timing of two weeks. It is likely that the number of food exposures needed to achieve acceptance varies by child’s age and may also vary between individual children and between target foods (Cooke, 2007). While 14 exposures were sufficient to increase intake and liking in the majority of children in this study, it is possible that further exposures could have been valuable for some of the intervention children who failed to increase their acceptance over the study period. It is also possible that for many children fewer than 14 exposures were necessary to modify their preferences. Further research is required to identify the optimal number of exposures needed to produce a sustained increase in children’s food acceptance.

9.5.2. Limitations

The ecological validity of the intervention is a major strength of this study; however there were several limitations to the design. Parents conducted the taste tests themselves and therefore strict experimental conditions could not be ensured. As a result, parents were also not blind to study condition, which could have resulted in inflated parental liking ratings in the intervention group after the intervention period or deflated liking ratings in the control condition. However, the similar pattern of findings observed for the more objective measure of intake suggests it was not just parental perception driving the intervention effect. It is also important to acknowledge the possibility of error or bias in parental reporting of vegetable intake. However, given the substantial intervention effect sizes, and the equal potential for error in both control and intervention conditions, this is unlikely to fully explain the study findings.

There was self-selection into the study to the extent that only 23% of parents who expressed initial interest and were randomised went on to return the outcome data record sheets. Nonetheless, outcome data were returned by a similar proportion of the control group who merely completed the three assessments of intake and liking (25%) to those in the intervention group who completed the assessments and the two week intervention procedure (21%). This suggests it was the burden of the three assessment sessions, rather than the ‘Tiny Tastes’ intervention, that acted as the major deterrent to study completion. The extent to which the intervention effect was maintained could not be assessed as no long-term follow-up data were collected. However, in previous studies the positive effects of rewarded exposure have been shown to endure for at least 3 months following similar intervention procedures (Remington et al., 2012).

9.5.3. Conclusions

Repeated taste exposure is an established technique that has been consistently shown to increase acceptance of disliked foods. However there is evidence to suggest parents usually only offer their children a disliked food on three to five occasions before giving up (Carruth et al., 2004; Maier, Chabanet, Schaal, Leathwood, et al., 2007) Additionally, a recent exploratory study investigating parental techniques for feeding vegetables to infants and toddlers found that the most popular maternal response to vegetable refusal was to give ‘vegetables by stealth’ (Caton et al., 2011). This refers to the practice of offering vegetables in a form whereby the child is not aware of their presence, i.e. disguising them in sauces, soups or hiding them in other food items. There is no evidence that this approach to increasing vegetable intake has any positive impact on liking. This indicates that the message of repeated exposure, although clearly supported by the literature, has not yet reached the wider public. Moreover, recent research has shown that the provision of sticker rewards facilitates the multiple tastings necessary for achieving acceptance (Corsini et al., 2013; Remington et al., 2012).

The present study extends previous findings and clearly demonstrates that parents can be taught to carry out exposure techniques using exclusively mailed materials and access to an online video. These simple, stand-alone materials enabled parents to implement a taste exposure protocol, and successfully increase their child’s acceptance of disliked vegetables without the need for one-to-one contact with researchers. Participating parents were enthusiastic about the taste exposure strategy. Wider dissemination of the programme has the potential to have a positive impact on the quality of children's diets.

The difference between the intervention and control groups in the percentage of children remaining in the non-eaters category post-intervention suggests that a sticker reward combined with repeated exposure outside of mealtimes may be effective in encouraging even some of the most reluctant children to taste and accept unfamiliar or previously disliked vegetables. However there remained a small number of children for whom the intervention did not work, and some who refused to taste any of their target vegetable throughout the study period. Exposure-based learning is dependent on physically tasting the rejected or avoided food and it seems that overcoming the hurdle of this initial taste is a major challenge for some children. While sticker rewards may be sufficient for many children to overcome this hurdle, this is not the case for everyone. Study 6 attempts to further understanding of this issue by examining the genetic and environmental determinants of the relative success of the 'Tiny Tastes' intervention for individual children.

CHAPTER 10 . STUDY 6: ARE GENES OR THE ENVIRONMENT DRIVING VARIATION IN RESPONSES TO THE 'TINY TASTES' INTERVENTION?

10.1. Background

The 'Tiny Tastes' repeated exposure intervention (Study 5, Chapter 9) resulted in significantly increased acceptance of a previously disliked vegetable in intervention group children compared to a no-treatment control group. The intervention effect size at a group level was large, but at an individual level there was still variation, with a minority of children who did not respond. The success of an intervention is generally measured in terms of an overall group effect, and as a result, few studies examine the causes and extent of variation in individual participants' responses to a particular intervention protocol. Insight into the causes of this variability, for example whether they are genetically or environmentally driven, could either avoid 'wasting' the intervention on those for whom it would bring no benefit or enable the tailoring of specific intervention programs to individual needs, i.e. the 'personalisation' of behavioural interventions.

There is significant variability in patients' response to pharmaceutical interventions, much of which has a genetic basis. Research into genetic influences in individual responses to drugs, pharmacogenetics, dates back to the 1950's but has received more attention in recent years (Gardiner & Begg, 2006). Technological advancements have enabled the identification of specific genes and single nucleotide polymorphisms (SNPs) that vary between individuals. The expression of these genetic differences can affect individual responses to drugs (Shastry, 2005). The classical twin design was used in several early pharmacogenetics studies to show that heritable factors play an important role in drug metabolism (Evans, 1968; Weber & Hein, 1979). Although twin models have fallen slightly out of favour in modern pharmacogenetics, a recent review highlighted the potential of this design for research in this field (Rahmioğlu & Ahmadi, 2010). The authors argue that the twin model offers a 'powerful tool' for investigating the source of population variability in complex phenotypes, including drug response.

Quantifying the genetic and environmental contributions to individual responses to a behavioural intervention is considerably more complicated. While a clear genetic basis for variability in drug response seems plausible, it is less certain whether genes could influence responses to behavioural interventions. Additionally, it is not clear what unique aspects of an individual (e.g. personality, temperament, motivation) or the environment (e.g. the individual delivering the intervention, home environment, social class or ethnic background etc.) contribute to their intervention response, and it is therefore impossible to adequately control for these potentially confounding variables at the participant level. One potential method for addressing these issues is the twin design. Quantitative genetic analyses using twin data can apportion the relative contribution of the environment (shared and unique) and genes to variation in a particular phenotype. In this case, the target phenotype is the intervention response. Comparing the degree of resemblance for the intervention response between monozygotic (MZ) and dizygotic (DZ) twins (who share 100% and 50% of their genes respectively) would provide an estimate of the extent of genetic influence. Furthermore by comparing the extent of MZ resemblance and the heritability of the phenotype it is possible to estimate of the size of the shared environment effect provided the sample size is sufficiently large.

10.2. Study aims

This study aims to (i) examine genetic and environmental influences on children's responses to the 'Tiny Tastes' intervention (ii) to apportion environmental influences to those that are shared between twin pairs and those that are unique to each individual child.

10.3. Methods

10.3.1. Sample

Participants were 3- 4 year old twins participating in the Gemini study (the cohort is described fully in Chapter 4). A sub-sample of 221 Gemini families took part in the 'Tiny Tastes' intervention; a randomised controlled trial of parent-administered taste exposure with the aim of increasing children's vegetable acceptance (described fully in Chapter 9). Families were randomised into a control or intervention condition, stratified by twin zygosity, to ensure equal representation of MZ and DZ twins in each condition. This study uses data from the 98 intervention families (196 twins) who completed the intervention condition (65 DZ and 33 MZ pairs).

10.3.2. Statistical analyses

10.3.2.1. Descriptive statistics on outcome variables

The study used a double pre-test, randomised, controlled, design as this permitted between group analyses of the treatment effect (follow-up, controlling for baseline), as well as within-group comparisons between the two baseline tests, and between the baseline and follow-up tests. As acceptance increased over the non-intervention phase between the two baselines (a common finding in exposure studies and thought to be due to testing) these analyses use scores from the first test (baseline 1), arguably the 'true' baseline. Acceptance was measured with two outcome variables; intake and liking. The size of the intervention effect was comparable for the two outcome variables, so given that intake was measured relatively objectively, while liking was parent-rated, intake change scores were used as the outcome measure in these analyses. Intake change scores were calculated by subtracting intake in the first baseline test session scores from intake in the post-intervention session.

10.3.2.2. Heritability analyses

Intraclass correlations in baseline intake and intake change scores were compared between MZ and DZ pairs, to quantify the extent to which baseline intake and responses to the intervention were determined by genetic and environmental factors. We conducted all analyses on scores that had been residualised for age- and sex-effects using a regression procedure. Intraclass correlations were calculated using SPSS version 20 for Windows.

Structural equation modelling (SEM) was achieved using Mx Modelling Software (version 32, Virginia Commonwealth University, Richmond VA). Univariate SEM was described in detail in Chapter 7. Briefly, SEM is used because it provides more precise estimates, 95% confidence intervals (CIs) and allows testing of the goodness of fit of different types of models. Using the covariance between the twins, SEM apportions the total variance in scores to additive genetic effects (A), shared environmental effects (C) and unique environmental influences (E) which also includes measurement error (Rijsdijk & Sham, 2002). Ninety five percent confidence intervals (CI) are estimated for component of variance and the goodness of fit for the full ACE model is provided by comparing it to an unrestrained model that includes only variances, covariances and means. More parsimonious sub-models can then be compared to the full ACE model, and parameters dropped if the goodness of fit of the sub-model is not compromised. Sub-models consecutively drop A, C, and both A and C together; the E component is always retained because it includes error of measurement (Neale, Boker, Xie, & Maes, 2003). Aikaike's Information Criterion (AIC) compares goodness of fit of the models while accounting for sample size. In comparisons between the complete ACE model and the nested sub-models, lower AIC values suggest better fitting models (Burnham & Anderson, 2002).

10.4. Results

10.4.1. Summary statistics

The characteristics of the sample are shown in Table 10.1. The sample was approximately half male (51%) and half female (49%). One third (34%) of the twin pairs were MZ. This is comparable to the full Gemini cohort (50% male and 31% MZ). Half of the mothers' participating in the intervention were university educated (51%), which is higher than for the full cohort (42%: χ^2=6.29, p=0.012).

Intervention children were consuming on average 2 pieces of their test vegetable at baseline. The mean intake change score illustrates the success of the intervention at a group level, with children eating on average 4 more pieces of the test vegetable at follow-up (see Table 10.2). A detailed description of the mean group effects of the intervention compared to a control group are provided in Chapter 9.

10.4.2. Heritability analyses

10.4.2.1. Intraclass correlations

Intraclass correlations for intake by zygosity are shown in Table 10.2. The intraclass correlations for baseline intake scores were higher for MZ twin pairs than DZ twin pairs, suggesting that individual differences in the amounts of vegetable children consumed in the pre-intervention behavioural assessment were partially genetically determined. In contrast, the intraclass correlation for intake change was slightly higher for DZs than for MZs. This indicates no heritability in the effect of the intervention on vegetable intake.

Table 10.1: Characteristics of the analysis sample (n=196 children)

Characteristic	**n (%)** or **mean (SD)**	
Twin pairs[a]		
MZ	33	(33.7)
DZ	65	(66.3)
Sex		
Males	100	(51.0)
Females	96	(49.0)
Age[b] **(years)**	3.9	(0.3)
Maternal age[c] **(years)**	38.0	(4.8)
Maternal education		
Below university level	96	(49.0)
University level or above	100	(51.0)

[a] MZ, monozygotic; DZ, dizygotic.
[b] Age of children when family completed the intervention.
[c] Age of mother when family completed the intervention.

Table 10.2: Means and intraclass correlation coefficients (and 95% CI) for baseline and change scores

	Mean (SD)	**Zygosity**[a]	**ICC**[b]	**(95% CI**[c]**)**	**N**
Baseline intake	1.94 (3.79)	MZ	0.50	(0.19-0.72)	33
		DZ	0.34	(0.10-0.54)	65
Intake change score	4.40 (7.73)	MZ	0.63	(0.36-0.78)	33
		DZ	0.73	(0.60-0.83)	65

[a] Zygosity of twin pair; MZ = monozygotic, DZ = dizygotic
[b] ICC = intraclass correlation coefficient
[c] CI= confidence interval

10.4.2.2. Model-fitting analyses

The results of the model-fitting analyses on baseline and change intake scores are shown in Table 10.3.

The heritability estimate for baseline vegetable intake was large (62%), with the remaining variance explained by unique environmental effects (38%). Shared environment effects did not contribute to variation in baseline intake (0%). The best-fitting sub-model for baseline intake dropped the shared environment parameter (C), and then demonstrated a significant genetic effect of the same magnitude (62%, 95% CI = 37-77%).

In contrast to the baseline intake scores, the full ACE model indicated that variation in intake change scores were largely attributable to the shared environment (58%), with the remaining variance divided between genetic (22%) and unique environment (20%) effects. However, the fit statistics for the full and nested sub-models favoured the sub-model that dropped the genetic component of variance, indicating that environmental effects contributed most to individual differences in change in intake scores.

Table 10.3: Model fit and parameter estimates (95% confidence intervals) for covariance model-fitting for baseline and change scores [a]

	Model[b]	Additive Genetic Effect (a^2)	Shared Environment Effect (c^2)	Non-shared Environment Effect[d] (e^2)	-2LL[c]	df	AIC[c]	Δ AIC	$\Delta\chi^2$ (df)	*p value*
BASELINE	ACE	0.62 (0.00–0.77)	0.00 (0.00-0.43)	0.38 (0.23-0.69)	427.046	191	45.046	-	-	-
INTAKE	CE	-	0.37 (0.19-0.53)	0.63 (0.47-0.81)	430.412	192	46.412	1.366	3.366 (1)	0.067
(n=196)	**AE***	0.62 (0.37-0.77)	-	0.38 (0.23-0.63)	427.046	192	43.046	-2.000	0.000 (1)	1
	E	-	-	1.00 (1.00-1.00)	444.905	193	58.905	13.859	17.859 (2)	<0.001
INTAKE	ACE	0.22 (0.00-0.52)	0.58 (0.31-0.78)	0.20 (0.12-0.37)	538.878	191	156.878	-	-	-
CHANGE	**CE***	-	0.71 (0.60-0.80)	0.29 (0.20-0.40)	540.635	192	156.635	-0.243	1.757 (1)	0.185
SCORE	AE	0.82 (0.71-0.89)	-	0.18 (0.11-0.28)	552.279	192	168.279	11.401	13.401 (1)	<0.001
(n=196)	E	-	-	1.00 (1.00-1.00)	610.219	193	224.219	67.341	71.341 (2)	<0.001

[a] Adjustments to scores: scores modelled were residuals adjusted for age and sex of the child.

[b] Statistical analyses: Standard ACE model-fitting analyses for continuous data were used. CE, AE and E models are nested within the full ACE model. The ACE model dissects the phenotypic variance into a^2, c^2 and e^2; the CE model drops the a^2 parameter and assesses variance explained by c^2 and e^2 only; the AE model drops the c^2 parameter and assesses the variance explained by a^2 and e^2 only; the E model drops both the a^2 and c^2 parameters and assesses the variance explained by e^2 only. Two fit indices are reported from the structural equation modelling analyses to evaluate sub-models against the full ACE model: *P* value based on the likelihood ratio chi-square test and Akaike's information criterion (AIC). The best-fitting model for each score is indicated with an *.

[c] Abbreviations: -2LL, -2 log likelihood; df, degrees of freedom; AIC, Akaike's Information Criterion.

[d] Includes measurement error.

* Indicates the best-fitting model (that does not represent a significant worsening of fit compared to the full ACE model).

10.5. Discussion

10.5.1. Summary of findings

To my knowledge this is the first study to utilise the twin design to investigate variation in responses to a behavioural intervention. While baseline intake of the test vegetable was found to be highly heritable, differences in intervention response (i.e. change in intake from baseline to post-intervention) were driven by aspects of the shared and unique environment. This is encouraging because it suggests that provided the optimal environmental conditions are identified, exposure interventions can increase children's acceptance of vegetables regardless of inherited susceptibilities towards rejecting vegetables.

Preferences for food groups and individual foods, including vegetables were found to be highly heritable in Chapter 7 of this thesis. Additionally, food fussiness was found to be 78% heritable in the Gemini sample (Chapter 8) while neophobia has similarly been reported as up to 78% heritable (Cooke et al., 2007; Faith et al., 2013). These findings help to explain the large genetic contribution to children's willingness to try a new or disliked vegetable found at baseline. In contrast, it was the shared environment that strongly influenced a change in intake resulting from the intervention. This suggests that neither neophobia nor fussiness mediate the effect of the intervention. In other words, while genetic factors were responsible for determining a child's initial willingness to eat the vegetable, shared environmental factors were driving their response to the intervention.

The particular aspects of the shared environment responsible for variation in intervention response cannot be identified in the present study, although a number of possible factors should be considered. As parents (usually mothers) delivered the intervention themselves, the individual responsible for intervention delivery was necessarily shared within twin pairs and is thus a factor of the shared environment. Therefore, the characteristics of the parent (i.e. temperament, parenting style), and the way in which they delivered the intervention (i.e. enthusiasm, consistency and engagement), may have contributed to children's responses. Likewise the study design required that same target vegetable be used for both twins in a pair, but the vegetable differed between families, so it is possible that different vegetables draw different intervention responses. Other aspects of the home environment during the period in which the intervention was conducted may also have contributed to its success (or otherwise). Chaos or stability within the home, family routine, the presence of older siblings and family trips or holidays are just a few factors that may have contributed to twin's shared experiences during the intervention. Furthermore, given the young age of the children at the time of intervention (four years) many of their prior experiences were likely to be shared within twin pairs, including both those inside and outside of the home (e.g. nursery, childcare, visits with grandparents etc.). Thus any prior history of contingent learning, or specific experiences of receiving stickers as behavioural rewards, is likely shared and could contribute to children's engagement with the intervention procedure, ultimately affecting the outcome.

The unique environment (i.e. the aspects of the environment experienced by one twin but not the other, or that affect each twin in a different way), also contributed to intervention responses and some environmental factors could be either shared within twins or experienced independently by individual children dependent on circumstance. Illness, especially gastro-intestinal disturbances, experienced over the intervention period likely influenced children's responses to the intervention. Such illnesses may have effected both twins concurrently (contributing to the shared environment effect) or only one child in a family (contributing to the unique environment effect). Other potential influences of the unique environment include the time of day the intervention was delivered to each child and their appetite and food experiences prior to each exposure session, as well and individual children's mood at each exposure session.

10.5.2. Limitations

There are several limitations to the present study design. The target vegetables differed across the sample, as parents were asked to select a vegetable that their own children disliked or had never tried. There may be heterogeneity in genetic and environmental responses to interventions with different vegetables, but given the variation in individual's food preference patterns it would be impractical to use the same vegetable for all children. In addition, comparisons of variance in change in intake scores between the different types of vegetables revealed no significant differences, which suggest vegetable type does not affect variations in children's intervention response.

The wide confidence intervals for the parameter estimates indicate the need for replication in larger samples. It was not possible to carry out a power analyses prior to this study as the design was novel and no predictions could be made about the magnitude of genetic and environmental effects. However, post hoc analyses revealed the study had only 41% power to detect a significant genetic effect of 22%; a sample size of 305 twin pairs would be required for 80% power to detect a significant genetic effect of this magnitude. It is therefore possible that there is a small genetic contribution to the effect of the intervention but that these analyses were unable to detect it given the relatively small sample size. Reassuringly, the sample was found to have 96% power to detect a shared environment effect of 58% as was found in the full ACE model of intake change, so we can be relatively confident of the shared environment estimates in these analyses.

Finally, although parents were asked to carry out the intervention separately with each twin, in reality this may not always have been practical for families and thus could have inflated the shared environment effect in this sample. If children completed either the exposure sessions or the behavioural test sessions alongside their sibling, facilitation of vegetable acceptance or conversely modelling of rejection may have driven within-pair similarities in intervention response.

10.5.3. Conclusion

Using a twin design to investigate individual differences in the outcome of behavioural interventions provides a novel approach for investigating why established intervention techniques work for some but not others. Despite several limitations, the current study highlights the potential for utilising the twin design within an intervention protocol. Furthermore, while the reduced power of the current analysis does not allow us to unequivocally rule out the existence of genetic contributions to children's responses to a food exposure intervention, the results do indicate that genes are only driving a very small proportion of this variation, if any. These finding suggest that if future research can successfully identify the environmental factors driving variation in children's responses to exposure interventions, this procedure could effectively increase vegetable acceptance for every child.

CHAPTER 11 . GENERAL DISCUSSION AND CONCLUSIONS

11.1. Introduction

The quality of children's diets is a matter of increasing concern globally. Diets typified by overconsumption of energy-dense low-nutrient food and low intake of nutrient-rich plant-based foods are progressively more common.

Children's food likes and dislikes are known to be a key predictor of their daily food intake, but understanding of the determinants of food preferences and their development in childhood remains limited. The aim of the research presented in this thesis was to address some of the gaps in the existing literature by investigating the aetiology and modification of food preferences in young children.

Firstly, data from the Gemini twin birth cohort were used to explore patterns of foods preferences longitudinally across infancy and early childhood. Then sociodemographic, family and child data from this same cohort were examined to identify how these characteristics related to food likes and dislikes in young children. The twin nature of the Gemini cohort enabled me to investigate the extent to which children's food preferences are determined by genetic or environment factors. Findings from these studies informed the design of an intervention to increase children's acceptance of previously rejected foods. In the final study, individual variation in responses to this intervention was explored. This chapter summarises the key findings of the work comprising this thesis and discusses the findings in terms of their contribution to the literature and implications for theory, practice and future research. The strengths and weaknesses of the specific approaches used in this thesis are also discussed.

11.2. Summary of thesis findings

Chapter 3 presented the primary aims of the thesis in the form of four questions, which were subsequently addressed in the study chapters (Chapters 6 to 10). The findings of this thesis are summarised here in relation to the original questions raised.

11.2.1. What patterns of food preferences are observed in infants and young children?

An exploration of the factorial structure of young children's preferences for multiple individual foods was conducted in order to avoid making suppositions about how preferences for different foods cluster together. The emergent structure of three year old children's food preferences was found to reflect traditional food categories (Study 1, Chapter 5). Five underlying factors explained preferences for vegetables, fruits, protein foods, dairy (and egg) foods and sweet and savoury snacks. The patterns of food preferences in young children were not consistent with a healthy diet, showing snack foods to be very well-liked, while vegetables were consistently among the least liked foods at both fifteen months and three years. More positively, fruit was found to be relatively well-liked at both time points. Preferences for all foods except snack foods decreased with age, suggesting that as children get older their liking for energy-dense foods that are implicated in excessive weight gain remain high, while liking for the healthy, nutrient-rich foods such as vegetables deteriorates.

11.2.2. What factors are associated with an increased liking for healthy and unhealthy foods in young children?

Study 2 (Chapter 6) explored predictors of children's food likes and dislikes at three years. Several aspects of the family feeding environment were associated with liking for fruit (breastfeeding, maternal fruit and vegetable intake) and vegetables (age at introduction of solids, maternal fruit and vegetable intake). However the strongest predictors were children's own eating behaviour traits: 'enjoyment of food' which was associated with higher liking for all foods except snacks, and particularly 'food fussiness' which was associated with lower liking for all food groups, but especially vegetables. Food fussiness was also found to increase between late infancy and early childhood, during the same period that liking for vegetables decreased.

11.2.3. To what extent are food preferences determined by genetic and environmental factors in infancy and early childhood?

The relative contributions of nature and nurture to children's food preferences were investigated separately at 15 months and 3 years, as well as longitudinally across this age-range in Study 3 (Chapter 7). The results indicated moderate heritability for all food groups at both ages with heritability increasing from 15 months to 3 years for each food group. At age three, genetic influence was substantial for fruits, vegetables and proteins, but lower for dairy and snacks. In contrast, shared environment effects were substantial for snacks and dairy, but lower for vegetables, fruits and protein. Non-shared environment effects were small for all foods. These findings suggest that variation in liking, particularly for the healthy, nutrient-rich foods, is primarily genetically determined, while the home food environment is the main determinant of children's preference for energy-dense snack foods. Food fussiness was also highly heritable, with a minimal influence of the unique environment (Study 4, Chapter 8).

A multivariate genetic analysis revealed common genetic influences underlying variation in vegetable preference, fruit preference and food fussiness (Study 4, Chapter 8). The strongest phenotypic and genetic correlations were between food fussiness and vegetable liking, with the majority of the association between these two factors explained by common genetic influences. Fussy children frequently dislike vegetables, and common genes appear to be driving both of these traits. Although a slightly smaller phenotypic correlation was observed between food fussiness and fruit liking, the largest proportion of this association was also explained by common genetic influences.

11.2.4. Can a mere exposure intervention be delivered cost effectively?

The findings of Study 5 (the 'Tiny Tastes' intervention) were that mailed advice for parent-delivered taste exposure, in conjunction with small non-food rewards, increased young children's vegetable acceptance and intake. Effects were similar to previous, more intensive interventions, in which parents received specialist researcher-delivered training in exposure plus reward procedures.

Despite the large intervention effect size observed in Study 5, some children failed to respond to 'Tiny Tastes' and their vegetable acceptance did not improve over the study period. The final study of this thesis (Study 6, Chapter 10) exploited the twin design to investigate individual differences in responses to the 'Tiny Tastes' intervention. While children's vegetable intake prior to the intervention was largely genetically determined, change in intake over the intervention period was primarily driven by shared environmental influences, with little or no genetic contribution.

Together, Studies 4, 5 and 6 suggest that vegetable liking is partially genetically determined, but that vegetable acceptance can be modified through an appropriately targeted, low cost intervention. Furthermore the extent to which these interventions are successful results from environmental, not genetic factors. In other words, the reason some children fail to respond to a repeated exposure intervention primarily results from aspects of the environment in which the intervention was delivered rather than inherited characteristics of the child themselves.

11.3. Implications for theory and intervention work

Liking for all foods except energy-dense snack foods were found to decrease between late infancy and early childhood. Fussy eating also seems to increase over this period. Thus, over the first few years of life, children's food preferences increasingly deviate from the pattern necessary for optimal nutrition. Furthermore, genetic influences on liking for all foods were found to increase over this early life period. Taken together these findings highlight the need to intervene early to modify children's food preferences if healthier dietary patterns are to be achieved.

It is a common misconception that genetic influences on traits, such as food preferences, render environmental intervention pointless. Environmental influences on food preferences, especially in early childhood were described at length in Chapter 1, and the important contribution of early dietary experiences was further supported by the findings of Study 2 (Chapter 6). Moreover, without certain permissive environmental conditions many genetic phenotypes would not be expressed – e.g. if fruit is not freely available in the home or offered to a young child, this child would not have the opportunity to express a preference for fruit, even if they were genetically predisposed to like it. Nevertheless, the findings of this research suggest that late infancy (up to 15 months) may provide a better opportunity for environmental intervention than later in childhood; although environmental influences on liking for fruits and vegetables were still moderate at age three, indicating that food preferences in this age group are likely to be susceptible to intervention.

Study 2 identified a number of potentially modifiable characteristics of the family food environment that were associated with preferences for both 'healthy' and 'unhealthy' foods, highlighting key areas to target in future interventions. Higher maternal fruit and vegetable intake was found to relate to increased liking for all foods except snacks at three years, suggesting parents should be informed about the importance of their own diet when encouraging healthy food preferences in their children. The findings of increased liking for all foods (except vegetables), among children who were breastfed supports existing literature on the potential benefits for later food acceptance and dietary variety conferred by breastfeeding (Cooke et al., 2004; Nicklaus et al., 2005; Schwartz et al., 2012). Breastfeeding promotion could also usefully incorporate information on the potential future benefits for greater food acceptance, as well as advice on increasing variety in their own diet during lactation.

Fussy children were found to be at risk of decreased preferences for all foods with the possible exception of energy-dense snacks (Study 2). Although rejection of nutritious foods such as vegetables is common among young children (Birch, 1999; Dovey et al., 2008), it is nonetheless a significant cause of anxiety to parents. Family mealtimes with fussy children can become a source of stress, that in turn may negatively impact on children's eating behaviour (Mitchell, Farrow, Haycraft, & Meyer, 2013). This could mean parents of fussy children resort to offering unhealthy foods in order to avoid confrontation, and to ensure their child meets his or her caloric needs. Parents of fussy children require support and guidance if overconsumption of less commonly rejected, highly palatable foods is to be avoided.

The finding of differential contributions of genes and environments on liking for nutrient-rich versus energy-dense foods also carries implications. Shared environmental influences were the strongest determinants of children's liking for energy-dense snack foods. This suggests that advice to parents on preventing the development of 'unhealthy' preferences should focus on restricting availability of energy-dense snacks in the home, particularly in early life. In contrast, genetic factors were the strongest determinant of liking for nutrient-rich foods such as fruits and vegetables. Interventions attempting to increase liking for these commonly rejected foods would benefit from directly targeting aspects of the child themselves, rather than simply focussing on the family feeding environment.

As discussed in Chapter 2, previous attempts to increase young children's acceptance of vegetables through modifications of the home and/or school environment have generally reported small or no effects (Haire-Joshu et al., 2008; Vereecken et al., 2009). Simply modifying the home environment or increasing availability of vegetables does not seem sufficient to increase children's acceptance of these foods, although increasing availability of fruit has improved intake in some circumstances (Vereecken et al., 2009). The finding of a strong association between food fussiness and vegetable liking (Study 2), and the discovery that common genes contribute to fussiness, and vegetable and fruit liking (Study 4), suggests that interventions aimed at modifying preference could benefit from targeting food rejection at the individual level. Treatment of 'phobias' in non-food domains typically involve some form of exposure to the phobic stimulus, often conducted in a graduated fashion (Choy, Fyer, & Lipsitz, 2007). It is no coincidence that 'neophobia' literally translates as a fear of the new, and food fussiness includes both the rejection of novel and known foods. Given the phenotypic (and genetic) association between food preferences and fussiness it is perhaps unsurprising that the most consistently effective techniques for increasing preference for vegetables involve small, repeated exposures to these rejected foods (Cooke, 2007). Furthermore, it is conceivable that repeated exposure to rejected fruit or vegetable stimuli, may lead not only to increased preference for the targeted food but also for plant-based foods generally, as well as a decrease in food fussiness.

Although successful, previous exposure-based interventions to modify food preferences have been both labour and resource intensive. Furthermore, evidence suggests the message of repeated exposure is not reaching parents (Carruth et al., 2004; Maier, Chabanet, Schaal, Leathwood, et al., 2007). If parents themselves are not educated about the use of repeated exposure in response to food refusal, counterproductive strategies may be adopted that could exacerbate the problem (Blissett, 2011; Caton et al., 2011). The randomised controlled trial of the 'Tiny Tastes' intervention (Study 5, Chapter 9) successfully validated a genuinely disseminable resource that has the potential to benefit children and families at a population level. As a result of the study's success, the 'Tiny Tastes' pack has been made available for purchase and steps are being taken to promote this valuable health resource to mothers and health workers nationally.

11.4. Limitations

There were a number of limitations in this thesis that warrant discussion. These are described in detail in sections 11.4.2. to 11.4.4. below.

11.4.2. Design and measurement issues

The issues associated with using parent-report measures of children's behaviour have been mentioned throughout this thesis. The longitudinal comparisons of parent-reported food preferences and eating behaviours are likely to have been affected by the child's capacity to communicate effectively. As children get older their ability to verbalise their dislikes improves, and as a result parents may perceive the rejection of a common food as being stronger. However with very young children, such as the fifteen month olds participating in the present research, no viable alternative to parent-report exists. Furthermore, parental reports of children's behaviours are commonly used in both behavioural and nutrition research (Wardle, Guthrie, Sanderson, &

Rapoport, 2001) and parent-report procedures for measuring children's' food preferences specifically are considered adequate and reliable (Pliner & Pelchat, 1986).

The theoretical concept of fussy or picky eating emerged relatively recently in the literature and there have been issues with conceptualising and measuring this behaviour. While the measure used in this thesis is more comprehensive than in many studies, which have attempted to characterise fussiness by simply asking a caregiver if they considered their child a picky eater (Carruth et al., 2004), it would nonetheless benefit from behavioural validation. Fussiness incorporates willingness to try both familiar and novel foods and consequently food neophobia is a necessary constituent of fussy eating. The CEBQ scale of food fussiness reflects this by including questions about the rejection of both new and all foods. However, as a result this measure cannot distinguish between the two behaviours. Neophobia forms part, but not all, of a fussy eater's behavioural profile and it has been suggested the characterisation of highly fussy children who have low levels of food neophobia (if such children exist) could elucidate the discrimination of these two concepts. Future research could benefit from the development of a measure that discriminates between fussy and neophobic behaviours.

Although the exploration of factors associated with children's foods preferences (Study 2, Chapter 6) included many potentially associated child, family and sociodemographic characteristics, it was by no means fully comprehensive. Other correlates of children's food acceptance including parental feeding behaviours, food availability and accessibility in the home, and parenting styles have been identified in the literature (Birch, 1998b; Cullen et al., 2003; Fisher & Birch, 1999; Galloway, Fiorito, Francis, & Birch, 2006; Pearson et al., 2009; Rasmussen et al., 2006) but their inclusion was beyond the scope of the current research. Similarly investigating the longitudinal associations between children's food preferences and fussiness at three years and adiposity at later ages would have helped clarify the relationship between these characteristics. Gemini is a large prospective study, anthropometric data has currently been collected until age six (and beyond) and recent data collection has included measures of the home environment and parental feeding behaviours, so it will be possible to address some of these questions in the future.

There are several limitations to the design of the 'Tiny Tastes' intervention (Study 5). As parents themselves collected the data that constituted the study outcome measures, strict experimental conditions could not be ensured. It was not possible to blind parents to the study condition which could have resulted in inflated parental liking ratings in the intervention group or deflated liking ratings in the control condition in the follow-up taste test. This would have caused an overestimation of the true intervention effect size. However, comparable patterns were observed for liking ratings and the more objective measure of intake - which implies group differences were not simply an artefact of parental perception or desirability bias. Similar results from studies where the outcome was measured objectively by independent researchers provide additional support for the Tiny Taste study findings. There was also the potential for error or bias in parental reporting of vegetable intake but the large intervention effect sizes, and the equal possibility for error in both control and intervention conditions, suggests these factors cannot fully explain the study findings. As no long-term follow-up data were collected it is not possible to draw firm conclusions regarding the enduring nature of the intervention effect observed, although findings from previous studies using similar methodologies would indicate that the positive effects of rewarded exposure are maintained for at least three months (Corsini et al., 2013; Remington et al., 2012).

If the intervention group measures of vegetable intake were subject to parental reporting biases this may have also affected the findings of Study 10. Inflated reports of post-intervention vegetable intake among the intervention children could have contributed to the large environment effect, which was found to explain the majority of variation in children’s intervention response.

11.4.3. Generalisation to singletons and other populations

The five food groups that emerged from the principal components analyses in Study 1 would not necessarily generalise to other populations (Field, 2009). Replication of this factor structure, and confirmation of the internal reliability of these scales, is needed to confirm these empirically-derived dimensions of food preference in other samples. Heritability estimates are also sample-specific and so findings cannot necessarily be generalised to other populations.

Gemini is largely White-British and includes an over-representation of high SES families, so it would be useful to replicate the findings of this thesis in other ethnic and lower SES groups. The response rate for the ‘Tiny Tastes’ intervention was low, there was self-selection into the study and this sub-sample were of even higher SES than the full cohort, suggesting the ‘Tiny Tastes’ intervention would particularly benefit from replication in more varied populations. Furthermore, only a quarter of parents who expressed initial interest in the intervention went on to complete the study and return data record sheets. However, outcome data were returned by a similar proportion of families in the control group (who merely completed the three behavioural assessments) compared to the intervention group (who completed the 'Tiny Tastes' protocol plus the three behavioural assessments). This suggests it was the burden of the three assessment sessions, rather than the demands of the intervention itself, that acted as a major deterrent to study completion.

There have been general criticisms of using twins in research and it has been argued that twins are too dissimilar from singleton children to allow for the generalisation of findings from twin samples to the wider population (Bouchard & McGue, 2003). However, many previous authors have challenged this assertion concerning twin designs (Boomsma et al., 2002; Bouchard & McGue, 2003; Derks et al., 2006; Klump, Holly, et al., 2000) and there is little reason to suppose that twins are distinct from the general population when it comes to food likes and dislikes specifically. In Studies 2 and 5 which did not rely on the twin design, clustering within families was controlled for and analyses were repeated using one twin per family with no major differences in outcome. However twins *are* born smaller and earlier than singleton infants (Grumbach et al., 1986) which may have affected the analyses examining associations between weight and food preferences and could therefore undermine generalizability to singletons.

More reassuringly, the proportion of Gemini twins who were exclusively breast- or bottle-fed was comparable to singleton UK population data (Infant Feeding Survey, 2007). Also, the average age of Gemini infants when solid foods were first introduced was also very similar to national statistics (Infant Feeding Survey, 2007) indicating that findings related to these factors can be generalised to singletons with relative confidence.

11.4.4. Potential violations of the assumptions of the twin design

Complications can arise when assumptions of twin models are violated. The 'equal environment assumption' is paramount in the twin design and requires that the shared environment is equal for MZs and DZs. Violations of this assumption would undermine heritability estimates. Given the evidence discussed in Chapter 1 for the phenomenon of flavour transmission to a foetus in utero (Mennella et al., 2001; Mennella et al., 1995) there is a possibility that sharing a placenta makes twins' prenatal flavour exposure more (or less) similar due to differential transfer of compounds. Around two thirds of MZs share a placenta (i.e. are 'monochorionic') whereas all DZs have separate placentas[16] (i.e. are 'dichorionic'). This could constitute a potential violation of the equal environments assumption when estimating the heritability of food preferences. Accurate information on chorionicity is difficult to obtain and requires careful reporting from healthcare professionals involved in the delivery of the twins. It has been demonstrated elsewhere that the information parents in the Gemini study received from health professionals was often inaccurate (van Jaarsveld et al., 2012) and we did not have the reliable chorionicity information needed to test for differences. However, any enduring effect of differential flavour exposure in utero is likely to be minimal and to date relatively few flavour compounds have been shown to be transmitted through amniotic fluid (Cooke & Fildes, 2011; Mennella et al., 1995; Schaal, Marlier, & Soussignan, 1998).

Parental rating biases for twins may also have influenced the findings of this thesis - for example it is possible that parents of MZ twins score them more similarly on psychometric measures than they actually are because they believe them to be identical. However, information was available from the Gemini cohort about whether parents thought their twins were MZ or DZ. This information was previously used to test if parents who misclassified their MZ twins as DZs, or their DZ twins as MZs (according to the zygosity questionnaire and DNA confirmation), rated them as more or less similar on appetitive characteristics compared to parents who classified their twins correctly. The twin correlations were virtually the same for all the appetite scales, and estimates of heritability were very similar using different subgroups, suggesting that the heritability estimates were not influenced by parental biases (Llewellyn, 2011). There is no reason to assume food preferences are any more susceptible to parental biases than appetitive characteristics so we can be relatively confident that difference in correlations observed for MZs and DZs in this thesis reflect true genetic differences. Moreover multiple other studies have tested this assumption using mistaken zygosity information, similarly concluding twin alikeness is not influenced by twin labelling (Gunderson et al., 2006; Kendler, Neale, Kessler, Heath, & Eaves, 1993; Scarr & Cartersaltzman, 1979).

Assortative mating is an additional complexity to consider in studies of heritability. Assortative mating is non-random mating (Plomin et al., 2008) whereby individuals reproduce with mates with whom they share similarities on certain traits. One example

---

[16] In extremely rare cases the two DZ placentas fuse, giving the appearance that they are monochorionic (Hall, 2003).

of this is weight or BMI where studies have reported a spousal correlation of about 0.1-0.2 (Allison et al., 1996; Silventoinen, Kaprio, Lahelma, Viken, & Rose, 2003). In twin studies assortative mating on a given trait serves to lower heritability estimates slightly as a result of inflated genetic similarity between DZ twins, leading to higher DZ correlations. The correlation between MZ twins remains the same (because the genetic relatedness of MZs remains unaffected at 100%), decreasing the difference between MZs and DZs. This results in lower estimates of heritability and higher estimates of the shared environment. Data on parental food preferences and food fussiness were not collected in Gemini so it was not possible to test for assortative mating on these traits.

It seems likely that increases in heritability over time at least in part result from genotype-environment correlations, whereby individuals with a greater preference for certain foods seek out these foods, increasing their environmental exposure to them and thereby reinforcing their preferences.

Gene-environment correlations can lead to overestimations of measured heritability in twin studies. ‘Active’ gene-environment correlation occurs when individuals are genetically predisposed to select environmental exposure and ‘evocative’ gene-environment correlation occurs when an individual's genetically influenced behaviour elicits an environmental response (Plomin et al., 2008). Heritability estimates include both the sum of genetic influences, and gene-environment correlations. It is conceivable that the heritability estimates of children’s food preferences and food fussiness may partly reflect both ‘active’ and ‘evocative’ gene-environment correlations. Children who display a heightened preference for certain foods are likely to be given these foods more frequently and they may also actively seek them out. This would result in increased environmental exposure to already preferred foods and strengthening of these underlying preferences. Similarly mothers may respond to children who display fussy eating behaviours and food rejection, by narrowing the variety of new foods they offer and failing to re-offer a previously rejected food, thereby exacerbating these behaviours. This process can reinforce a trait by causing the genetic influences on a phenotype to ‘snowball’, increasing phenotypic variance in a population, and heightening similarities between more genetically related individuals (i.e. MZs versus DZs) which in turn increases heritability estimates (Plomin et al., 2008).

11.5. Future directions

The work described in this thesis highlights several potential areas for future research. The finding of increased liking for vegetables among children who were introduced to solid foods earlier is novel and requires replication. The issue of the timing of introduction of complementary foods into an infant's diet has received recent widespread academic, press and public attention, and is a highly contentious topic. The evidence presented to support recommendations for delaying complementary feeding until 6 months has generally focused on issues such as risk of infection, food sensitization and nutritional adequacy and is by no means unequivocal (Fewtrell et al., 2007). Although most researchers and health professionals agree that complementary feeding should not begin before 4 months, the health implications of delaying complementary feeding until 6 months in developed countries remain uncertain. Further research into the possible impact of delaying solid food introduction on later food preferences is needed, and the possibility of a negative behavioural impact of later weaning should be considered when guidance in optimal timing for the introduction of complementary feeding is formulated.

Appetitive traits were found to relate to likes and dislikes for all food groups at three years of age. Enjoyment of food was significantly associated with increased liking for all foods apart from snacks, while food responsiveness was only related to liking for snack foods. In addition, the relationship between food fussiness and liking for snack foods was much weaker than that with other food groups. Taken together these findings suggest inherent differences in the mechanisms behind liking for sweet and savoury energy-dense snack foods in comparison to other 'core' foods. It seems children who enjoy food generally (i.e. those who score highly on the 'enjoyment of food' scale) do not display higher than normal preferences for the foods universally liked from the outset, such as sweet and salty energy-dense foods. In contrast, young children who score highly on 'food responsiveness' appear to be particularly susceptible to the hedonic rewards of palatable foods compared to their less 'food responsive' peers. However, further exploration of the relationship between characteristics of children's appetitive behaviours and preferences for various foods and food properties are required. Given that a number of studies have implicated both 'enjoyment of food' and 'food responsiveness' in obesity risk, with both appetitive characteristics being associated with higher BMI (Carnell & Wardle, 2008; Spence, Carson, Casey, & Boule, 2011; Viana et al., 2008; Webber et al., 2009), the implications of the apparently differential relationships between each of these characteristics and food preferences remains unclear.

Study 5 also contributes to the literature on the use of rewards in child feeding. The findings are consistent with previous evidence indicating that for initially disliked food items, the use of incentives can increase young children's liking and consumption, both at school and in the home (Cooke, Chambers, Anez, Croker, et al., 2011; Corsini et al., 2013; Remington et al., 2012). However, there are several questions that remain unanswered. It is possible that repeating the 'Tiny Tastes' protocol for the same child for multiple foods could result in decreased efficacy of the programme due to a decline in the reinforcing value of sticker rewards. It would also be interesting to investigate the impact of 'Tiny Tastes' on food fussiness generally, rather than simply on acceptance of the individual target vegetable. If the repeated exposure plus reward protocol improves acceptance of a specific food by addressing fussy or neophobic behaviours, it is plausible that the treatment effects of this programme extend beyond the targeted stimuli, to other rejected foods. Although we have no conclusive data from the 'Tiny Tastes' study to support this, anecdotal feedback from Gemini families who participated in the study does supports a generalizable effect of the intervention.

Despite the success of the 'Tiny Tastes' intervention at a group level, there were a small number of participating children who failed to respond positively to the intervention procedure. Study 6 is the first study to utilise quantitative genetic modelling techniques in order to explore individual variation in response to a behavioural intervention, and demonstrates the utility of the twin design for investigating the source of variability in responses to behavioural interventions. The findings have implications for the implementation of food exposure protocols. Genes were found to contribute very little, if at all, to the variation in children's responses to the 'Tiny Tastes' intervention. Future research should therefore concentrate on identifying the environmental factors driving variation in children's responses to exposure interventions. Successfully identifying these predictors could ensure the correct implementation of the 'Tiny Tastes' procedure and result in the successful modification of vegetable acceptance for every participating child.

Finally, finding such a large genetic component to vegetable liking, fruit liking and food fussiness, and also the genetic commonality between these traits, suggests that the identification of molecular genetic variants influencing these behaviours would be worthwhile. If related genes could be identified, there would be the possibility of identifying individuals who are 'at risk' for an unhealthy pattern of food preferences (i.e.

strong dislike for vegetables and fruits) or extreme food fussiness and thereby direct interventions to where they are most needed.

11.6. Conclusion

Taken together the findings of this thesis suggest ‘prevention may be better than cure’ when it comes to some aspects of food preference. Parents can encourage healthier patterns of preference by concentrating on aspects of the early family feeding environment. However given the genetic contribution to food fussiness and liking for nutrient-rich foods in particular, it is likely that many children would display some level of food rejection irrespective of their early environment.

Parents, as the principal architects of young children’s environments, would benefit from evidence-based guidance on how best to foster healthy food preferences and eating habits using effective techniques such as repeated exposure, while preventing the development of ‘unhealthy’ preferences through restricting availability of energy-dense ‘snacks’ in the home. Thus, the findings of this thesis support the implementation of interventions, both directly targeting the modification of children’s individual preferences and those aimed at shaping the early food environment, to improve children’s diet quality.

REFERENCES

Addessi, E., Galloway, A. T., Visalberghi, E., Birch, L. L. (2005). Specific social influences on the acceptance of novel foods in 2-5-year-old children. *Appetite, 45,* 264-271.

Adler, E., Hoon, M. A., Mueller, K. L., Chandrashekar, J., Ryba, N. J., Zuker, C. S. (2000). A novel family of mammalian taste receptors. *Cell, 100,* 693-702.

Agostoni, C., Decsi, T., Fewtrell, M., Goulet, O., Kolacek, S., Michaelsen, K. F., … ESPGHAN Committee on Nutrition (2008). Complementary feeding: a commentary by the ESPGHAN Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition, 46*, 99-110.

Akaike, H. (1987). Factor-analysis and AIC. *Psychometrika, 52*, 317-332.

Allison, D. B., Neale, M. C., Kezis, M. I., Alfonso, V. C., Heshka, S., & Heymsfield, S. B. (1996). Assortative mating for relative weight: genetic implications. *Behavior Genetics*, *26*, 103-111.

Anderson, A. S., Porteous, L. E., Foster, E., Higgings, C., Stead, M., Hetherington, M., …Adamson, A. J. (2005). The impact of a school-based nutrition education intervention on dietary intake and cognitive and attitudinal variables relating to fruits and vegetables. *Public Health Nutrition, 8*, 650-656.

Antova, T., Pattenden, S., Nikiforov, B., Leonardi, G. S., Boeva, B., Fletcher, T., … Holikova, J. (2003). Nutrition and respiratory health in children in six Central and Eastern European countries. *Thorax, 58,* 231-236.

Anzman-Frasca, S., Savage, J. S., Marini, M. E., Fisher, J. O. & Birch, L. L. (2012). Repeated exposure and associative conditioning promote preschool children's liking of vegetables. *Appetite, 58,* 543-553.

Ashcroft, J., C. Semmler, Carnell, S., van Jaarsveld, C. H., Wardle, J. (2008). Continuity and stability of eating behaviour traits in children. European Journal of Clinical Nutrition 62, 985-990.

Bachmanov, A. Reed, A., Li, D. R., Beauchamp, G. K. (2002). Genetics of sweet taste preferences. *Pure Applied Chemistry 74, 7*, 1135-1140.

Baird, J., Fisher, D., Lucas, P., Kleijnen, J., Roberts, H. & Law, C. (2005). Being big or growing fast: systematic review of size and growth in infancy and later obesity. *British Medical Journal, 331,* 929.

Bandura, A. (1998). Health promotion from the perspective of social cognitive theory. *Psychology & Health, 13,* 623-649.

Bartley, M. (2004). Health inequality: an introduction to theories, concepts and methods. Cambridge, United Kingdom: Polity Press.

Bartoshuk, L. M. (1979). Bitter taste of saccharin related to the genetic ability to taste the bitter substance 6-n-propylthiouracil. *Science, 205,* 934-935.

Baxter, S. D. & Thompson, W. O. (2002). Fourth-grade children's consumption of fruit and vegetable items available as part of school lunches is closely related to preferences. *Journal of Nutrition Education and Behavior, 34,* 166-171.

Beauchamp, G. K., Cowart, B. J., Moran, M. (1986). Developmental changes in salt acceptability in human infants. *Developmental Psychobiology, 19,* 17-25.

Beauchamp, G. K., & Mennella, J. A. (2009). Early flavor learning and its impact on later feeding behavior. *Journal of Pediatric Gastroenterology and Nutrition, 48,* S25-S30.

Beauchamp, G. K., & Moran, M. (1982). Dietary experience and sweet taste preference in human infants. *Appetite, 3,* 139-152.

Bell, K. I., & Tepper, B. J. (2006). Short-term vegetable intake by young children classified by 6-n-propylthoiuracil bitter-taste phenotype. *The American Journal of Clinical Nutrition, 84,* 245-251.

Bellisle, F., Rolland-Cachera, M. F. Kellogg Scientific Advisory Committee (2000). Three consecutive (1993,1995,1997) surveys of food intake, nutritional attitudes and knowledge, and lifestyle in 1000 French children, aged 9-11 years. *Journal of Human Nutrition and Dietetics, 20, 241-251*

Benton, D. (2004). Role of parents in the determination of the food preferences of children and the development of obesity. *International Journal of Obesity and Related Metabolic Disorders, 28,* 858-869.

Bere, E. & Klepp, K. I. (2004). Correlates of fruit and vegetable intake among Norwegian schoolchildren: parental and self-reports. *Public Health Nutrition, 7*, 991-998.

Bergen, S. E., Gardner, C. O. Kendler, K. S. (2007). Age-related changes in heritability of behavioral phenotypes over adolescence and young adulthood: a meta-analysis. *Twin Research and Human Genetics, 10*, 423-433.

Birch, L. L. (1980). The Relationship between children's food preferences and those of their parents. *Journal of Nutrition Education, 12*, 14-18.

Birch, L. L. (1987). The role of experience in children's food acceptance patterns. Journal of the American Dietetic Association, 87, S36-40.

Birch, L. L. (1998). Development of food acceptance patterns in the first years of life. *Proceedings of the Nutrition Society, 57*, 617-624.

Birch, L. L. (1999). Development of food preferences. *Annual Review of Nutrition, 19*, 41-62.

Birch, L. L., Anzman-Frasca, S. & Paul, I. M. (2012). Starting early: Obesity prevention during infancy. In Drewnowski, A. and Rolls, B. J. (Eds.) *Obesity treatment and prevention: New directions*, *(*pp. 81–94.) Basel: Nestle Nutrition Institute Workshop Series.

Birch, L. L., Billman, J., & Richards, S. S. (1984). Time of day influences food acceptability. *Appetite, 5*, 109-116.

Birch, L. L., Birch, D., Marlin, D. W., & Kramer, L. (1982). Effects of instrumental consumption on children's food preference. *Appetite, 3*, 125-134.

Birch, L. L. & Deysher, M. (1986). Caloric compensation and sensory specific satiety: evidence for self-regulation of food intake by young children. *Appetite, 7*, 323-331.

Birch, L. L., Gunder, L., Grimm-Thomas, K., & Laing, D. G. (1998). Infants' consumption of a new food enhances acceptance of similar foods. *Appetite, 30*, 283-295.

Birch, L. L. & Marlin, D. W. (1982). I don't like it; I never tried it: effects of exposure on two-year-old children's food preferences. *Appetite, 3*, 353-360.

Birch, L. L., McPhee, L., Shoba, B. C., Pirok, E., & Steinberg, L. (1987). What kind of exposure reduces children's food neophobia?: Looking vs. tasting. *Appetite, 9*, 171-178.

Birch, L. L., McPhee, L., Steinberg, L., & Sullivan, S. (1990). Conditioned flavor preferences in young children. *Physiology & Behavior, 47*, 501-505.

Bjelland, M., Brantsaeter, A. L., Haugen, M., Meltzer, H. M., Nystad, W., & Andersen, L. F. (2013). Changes and tracking of fruit, vegetables and sugar-sweetened beverages intake from 18 months to 7 years in the Norwegian mother and child cohort study. *BMC Public Health 13*, 793.

Blissett, J. (2011). Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood. *Appetite*, 57, 826-831.

Boomsma, D., Busjahn, A., & Peltonen, L. (2002). Classical twin studies and beyond. *Nature Reviews Genetics, 3*, 872-882.

Borah-Giddens, J. & Falciglia, G. A. (1993). A meta-analysis of the relationship in food preferences between parents and children. *Journal of Nutrition Education, 25*, 102-107.

Pérusse L, Bouchard C. (1994) Genetics of energy intake and food preferences. In Bouchard C, (Ed.). *The Genetics of Obesity* (pp. 125–134). CRC Press.

Bouchard, T. J. & McGue, M. (2003). Genetic and environmental influences on human psychological differences. *Journal of Neurobiology, 54*, 4-45.

Breen, F. M., Plomin, R., & Wardle, J. (2006). Heritability of food preferences in young children. *Physiology & Behavior, 88*, 443-447.

Brown, A. & Lee, M. (2011). A descriptive study investigating the use and nature of baby-led weaning in a UK sample of mothers. *Maternal & Child Nutrition, 7*, 34-47.

Brown, A. & Lee, M. (2013). An exploration of experiences of mothers following a baby-led weaning style: developmental readiness for complementary foods. *Maternal & Child Nutrition, 9*, 233-243.

Bufe, B., Breslin, P. A., Kuhn, C., Reed, D. R., Tharp, C. D., Slack, J. P., . . . Meyerhof, W. (2005). The molecular basis of individual differences in phenylthiocarbamide and propylthiouracil bitterness perception. *Current Biology, 15*, 322-327.

Burnham, K. P., & Anderson, D. R. (2002). Model selection and multimodel inference: a practical information-theoretic approach (2nd ed.). New York: Springer.

Cameron, S. L., Heath, A. L., & Taylor, R. W. (2012a). Healthcare professionals' and mothers' knowledge of, attitudes to and experiences with, baby-led weaning: a content analysis study. *BMJ Open, 2*. e001542

Cameron, S. L., Heath, A. L., & Taylor, R. W. (2012b). How feasible is baby-led weaning as an approach to infant feeding? A review of the evidence. *Nutrients, 4*, 1575-1609.

Carnell, S., Haworth, C. M., Plomin, R., & Wardle, J. (2008). Genetic influence on appetite in children. *International Journal of Obesity, 32*, 1468-1473.

Carnell, S. & Wardle, J. (2007). Measuring behavioural susceptibility to obesity: validation of the child eating behaviour questionnaire. *Appetite, 48*, 104-113.

Carnell, S., & Wardle, J. (2008). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *American Journal of Clinical Nutrition*, 88, 22-29.

Carruth, B. R., Skinner, J., Houck, K., Moran, J., 3rd, Coletta, F., & Ott, D. (1998). The phenomenon of picky eater: a behavioral marker in eating patterns of toddlers. *The Journal of the American College of Nutrition, 17*, 180-186.

Carruth, B. R., Ziegler, P. J., Gordon, A., & Barr, S. I. (2004). Prevalence of picky eaters among infants and toddlers and their caregivers' decisions about offering a new food. *Journal of the American Dietetic Association, 104*, s57-64.

Carter, P., Gray, L. J., Troughton, J., Khunti, K., & Davies, M. J. (2010). Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *British Medical Journal, 341*, c4229.

Cashdan, E. (1994). A sensitive period for learning about food. *Human Nature: an Interdisciplinary Biosocial Perspective, 5*, 279-291.

Cashdan, E. (1998). Adaptiveness of food learning and food aversions in children. Social Science Information, 37, 613-632.

Caton, S. J., Ahern, S. M., & Hetherington, M. M. (2011). Vegetables by stealth. An exploratory study investigating the introduction of vegetables in the weaning period. *Appetite, 57*, 816-825.

Caton, S. J., Ahern, S. M., Remy, E., Nicklaus, S., Blundell, P., & Hetherington, M. M. (2012). Repetition counts: repeated exposure increases intake of a novel vegetable in UK pre-school children compared to flavour-flavour and flavour-nutrient learning. *British Journal of Nutrition, 109*, 2089-2097.

Cattell, R. B. (1966). The Scree test for the number of factors. *Multivariate Behavioral Research, 1*, 245-276.

Cederlof, R., Friberg, L., Jonsson, E., & Kaij, L. (1961). Studies on similarity diagnosis in twins with the aid of mailed questionnaires. *Acta Geneticae Miedicae et Gemollologiae, 11*, 338-362.

Cermak, S. A., Curtin, C., & Bandini, L. G. (2010). Food selectivity and sensory sensitivity in children with autism spectrum disorders. *Journal of the American Dietetic Association 110*, 238-246.

Chandola, T. & C. Jenkinson (2000). The new UK National Statistics Socio-Economic Classification (NS-SEC); investigating social class differences in self-reported health status. *Journal of Public Health Medicine, 22*, 182-190.

Chandrashekar, J., Mueller, K. L., Hoon, M. A., Adler, E., Feng, L., Guo, W., . . . Ryba, N. J. (2000). T2Rs function as bitter taste receptors. *Cell, 100*, 703-711.

Chinn, S. (2006). Obesity and asthma. *Paediatric Respiratory Review, 7*, 223-228.

Choy, Y., Fyer, A. J., & Lipsitz, J. D. (2007). Treatment of specific phobia in adults. *Clinical Psychology Review, 27*, 266-286.

Cole, T. J. (2009). Software for LMS method: LMSGrowth PC. [Computer software]

Cooke, L. (2007). The importance of exposure for healthy eating in childhood: a review. *Journal of Human Nutrition and Dietetics, 20*, 294-301.

Cooke, L., Carnell, S., & Wardle, J. (2006). Food neophobia and mealtime food consumption in 4-5 year old children. *International Journal of Behavioural Nutrition and Physical Activity, 3*. 14.

Cooke, L. J., Chambers, L. C., Anez, E. V., Croker, H. A., Boniface, D., Yeomans, M. R., & Wardle, J. (2011). Eating for pleasure or profit: the effect of incentives on children's enjoyment of vegetables. *Psychological Science, 22*, 190-196.

Cooke, L. J., Chambers, L. C., Anez, E. V., & Wardle, J. (2011). Facilitating or undermining? The effect of reward on food acceptance. A narrative review. *Appetite, 57*, 493-497.

Cooke, L. & Fildes, A. (2011). The impact of flavour exposure in utero and during milk feeding on food acceptance at weaning and beyond. *Appetite, 57*, 808-811.

Cooke, L. J., Haworth, C. M., & Wardle, J. (2007). Genetic and environmental influences on children's food neophobia. *American Journal of Clinical Nutrition, 86*, 428-433

Cooke, L. J. & J. Wardle (2005). Age and gender differences in children's food preferences. *British Journal of Nutrition, 93*, 741-746.

Cooke, L., Wardle, J., & Gibson, E. L. (2003). Relationship between parental report of food neophobia and everyday food consumption in 2-6-year-old children. *Appetite, 41*, 205-206.

Cooke, L. J., Wardle, J., Gibson, E. L., Sapochnik, M., Sheiham, A., & Lawson, M. (2004). Demographic, familial and trait predictors of fruit and vegetable consumption by pre-school children. *Public Health Nutrition, 7*, 295-302.

Corsini, N., Slater, A., Harrison, A., Cooke, L., & Cox, D. N. (2013). Rewards can be used effectively with repeated exposure to increase liking of vegetables in 4-6-year-old children. *Public Health Nutrition*, 16, 942-951.

Cortina, J. M. (1993). What Is coefficient alpha - an examination of theory and applications. *Journal of Applied Psychology, 78*, 98-104.

Coulthard, H. & Blissett, J. (2009). Fruit and vegetable consumption in children and their mothers. Moderating effects of child sensory sensitivity. *Appetite, 52*, 410-415.

Coulthard, H., Harris, G., & Emmett, P. (2009). Delayed introduction of lumpy foods to children during the complementary feeding period affects child's food acceptance and feeding at 7 years of age. *Maternal & Child Nutrition, 5*, 75-85.

Cullen, K. W., Baranowski, T., Owens, E., Marsh, T., Rittenberry, L., & de Moor, C. (2003). Availability, accessibility, and preferences for fruit, 100% fruit juice, and vegetables influence children's dietary behavior. *Health Education & Behavior, 30*, 615-626.

Currie, C., Roberts, C., Morgan, A., Smith, R., Settertobulte, W., Samdal, O., & V., B. R. (2004). Young people's health in context : health behaviour in school-aged children (HBSC) study : international report from the 2001/2002 survey. Copenhagen, World Health Organization Regional Office for Europe.

Cusatis, D. C., Chinchilli, V. M., Johnson-Rollings, N., Kieselhorst, K., Stallings, V. A., & Lloyd, T. (2000). Longitudinal nutrient intake patterns of US adolescent women: the Penn State Young Women's Health Study. *Journal of Adolescent Health, 26*, 194-204.

De Bock, F., Breitenstein, L., & Fischer, J. E. (2012). Positive impact of a pre-school-based nutritional intervention on children's fruit and vegetable intake: results of a cluster-randomized trial. *Public Health Nutrition, 15*, 466-475.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*, 627-668.

Delgado-Noguera, M., Tort, S., Martinez-Zapata, M. J., & Bonfill, X. (2011). Primary school interventions to promote fruit and vegetable consumption: a systematic review and meta-analysis. Preventive Medicine, 53, 3-9.

Department for Innovation, Universities and Skills. (2008). The level of highest qualification held by adults: England 2007. London, England: Department for Innovation, Universities and Skills. Retrieved from: http://webarchive.nationalarchives.gov.uk/20130401151655/http://www.education.gov.uk/researchandstatistics/statistics/allstatistics/

Derks, E. M., Dolan, C. V., & Boomsma, D. I. (2006). A test of the equal environment assumption (EEA) in multivariate twin studies. *Twin Research and Human Genetics, 9*, 403-411.

Desor, J. A., Maller, O., & Andrews, K. (1975). Ingestive responses of human newborns to salty, sour, and bitter stimuli. *Journal of Comparative and Physiological Psychology, 89*, 966-970.

Desor, J. A., Maller, O., & Turner, R. E. (1973). Taste in acceptance of sugars by human infants. *Journal of Comparative and Physiological Psychology, 84*, 496-501.

Diehl, J. M. (1999). Food preferences of 10- to 14-year-old boys and girls. *Swiss Medical Weekly, 129*, 151-161.

dos Santos Oliveira, L., de Lima, D. P., da Silva, A. A. M., da Silva, M. C., de Souza, S. L., & Manhães-de-Castro, R. (2011). Early weaning programs rats to have a dietary preference for fat and palatable foods in adulthood. *Behavioural Processes, 86*, 75-80.

Dovey, T. M., Staples, P. A., Gibson, E. L., & Halford, J. C. (2008). Food neophobia and 'picky/fussy' eating in children: a review. *Appetite, 50*, 181-193.

Drewnowski, A., Henderson, S. A., Hann, C. S., Berg, W. A., & Ruffin, M. T. (2000). Genetic taste markers and preferences for vegetables and fruit of female breast care patients. *Journal of the American Dietetic Association, 100*, 191-197.

Drewnowski, A., Henderson, S. A., Levine, A., & Hann, C. (1999). Taste and food preferences as predictors of dietary practices in young women. *Public Health Nutrition, 2*, 513-519.

Dubois, L., Farmer, A., Girard, M., Peterson, K., & Tatone-Tokuda, F. (2007). Problem eating behaviors related to social factors and body weight in preschool children: A longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity*, *4*, 9.

Eid, M., Riemann, R., Angleitner, A., & Borkenau, P. (2003). Sociability and positive emotionality: genetic and environmental contributions to the covariation between different facets of extraversion. *Journal of Personality, 71*, 319-346.

Emmett, P., Rogers, I., & Symes, C. (2002). Food and nutrient intakes of a population sample of 3-year-old children in the south west of England in 1996. *Public Health Nutrition, 5*, 55-64.

Epstein, L. H., Gordy, C. C., Raynor, H. A., Beddome, M., Kilanowski, C. K., & Paluch, R. (2001). Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. *Obesity Research, 9*, 171-178.

Evans, C. E., Christian, M. S., Cleghorn, C. L., Greenwood, D. C., & Cade, J. E. (2012). Systematic review and meta-analysis of school-based interventions to improve daily fruit and vegetable intake in children aged 5 to 12 y. *American Journal of Clinical Nutrition, 96*, 889-901.

Evans, D. A. P. (1968). Gentetic varitations in the acetylation of Isoniaxid and other drugs. *Annals of the New York Academy of Sciences, 151*, 723-733.

Fabsitz, R. R., Garrison, R. J., Feinleib, M., & Hjortland, M. (1978). Twin analysis of dietary Intake - evidence for a need to control for possible environmental differences in Mz and Dz twins. *Behavioral Genetics, 8*, 15-25.

Faith, M. S. (2005). Development and modification of child food preferences and eating patterns: behavior genetics strategies. *International Journal of Obesity and Related Metabolic Disorders, 29*, 549-556.

Faith, M. S., Heo, M., Keller, K. L., & Pietrobelli, A. (2013). Child food neophobia is heritable, associated with less compliant eating, and moderates familial resemblance for BMI. *Obesity, 21*, 1650-1655.

Falciglia, G. A. and P. A. Norton (1994). Evidence for a genetic influence on preference for some foods. *Journal of the American Dietetic Association, 94*, 154-158.

Falciglia, G., Pabst, S., Couch, S., & Goody, C. (2004). Impact of parental food choices on child food neophobia. *Childrens Health Care, 33*, 217-225.

Faust, J. (1974). Twin Study of Personal Preferences. *Journal of Biosocial Science, 6*, 75-91.

Fewtrell, M. S., Morgan, J. B., Duggan, C., Gunnlaugsson, G., Hibberd, P. L., Lucas, A., & Kleinman, R. E. (2007). Optimal duration of exclusive breastfeeding: what is the evidence to support current recommendations? *American Journal of Clinical Nutrition, 85*, 635s-638s.

Field, A. P. (2009). *Discovering statistics using SPSS*. London, England: SAGE.

Fieldstone, A., Zipf, W. B., Schwartz, H. C., & Berntson, G. G. (1997). Food preferences in Prader-Willi syndrome, normal weight and obese controls. *International Journal of Obesity and Related Metabolic Disorders, 21*, 1046-1052.

Fildes, A., van Jaarsveld, C. H. M., Wardle, J., & Cooke, L. (2013). Parent-administered exposure to increase children's vegetable acceptance: a randomized controlled trial. *Journal of the Academy of Nutrition and Dietetics*. (In Press).

Fisher, J. O. and L. L. Birch (1995). Fat preferences and fat consumption of 3- to 5-year-old children are related to parental adiposity. *Journal of the American Dietetic Association, 95*, 759-764.

Forastiere, F., Galassi, C., Biggeri, A., Richiardi, L., Baussano, I., Simoni, M., & Viegi, G. (2005). The proportion of respiratory disorders in childhood attributable to preventable and not preventable risk factors. *Epidemiologia & Prevenzione, 29*, 67-69.

Forestell, C. A. & Mennella, J. A. (2007). Early determinants of fruit and vegetable acceptance. *Pediatrics, 120*, 1247-1254.

Forestell, C. A. & Mennella, J. A. (2008). Food, folklore and flavor preference development. In: Lammi-Keefe, C., Couch, S. C., Philipson, E. (Eds.), Handbook of nutrition and pregnancy (pp. 55–64). Totowa, NJ: Humana Press.

Fox, M. K., Pac, S., Devaney, B., & Jankowski, L. (2004). Feeding Infants and Toddlers Study: What foods are infants and toddlers eating? *Journal of the American Dietetic Association, 104*, S22-S30.

Frayling, T. M., Timpson, N. J., Weedon, M. N., Zeggini, E., Freathy, R. M., Lindgren, C. M., . . . McCarthy, M. I. (2007). A common variant in the FTO gene is associated with body mass index and predisposes to childhood and adult obesity. *Science, 316*, 889-894.

Freeman, J. V., Cole, T. J., Chinn, S., Jones, P. R., White, E. M., & Preece, M. A. (1995). Cross sectional stature and weight reference curves for the UK, 1990. *Archives of Diseases in Childhood, 73*, 17-24.

French, G. M., Nicholson, L., Skybo, T., Klein, E. G., Schwirian, P. M., Murray-Johnson, L., . . . Groner, J. A. (2012). An evaluation of mother-centered anticipatory guidance to reduce obesogenic infant feeding behaviors. *Pediatrics, 130*, e507-517.

Gallaway, M. S., Jago, R., Baranowski, T., Baranowski, J. C., & Diamond, P. M. (2007). Psychosocial and demographic predictors of fruit, juice and vegetable consumption among 11-14-year-old Boy Scouts. Public Health Nutrition, 10, 1508-1514.

Galloway, A. T., Fiorito, L., Lee, Y., & Birch, L. L. (2005). Parental pressure, dietary patterns, and weight status among girls who are picky eaters. J*ournal of the American Dietetics Association, 105*, 541-548.

Galloway, A. T., Lee, Y., & Birch, L. L. (2003). Predictors and consequences of food neophobia and pickiness in young girls. *Journal of the American Dietetic Association, 103*, 692-698.

Galobardes, B., Shaw, M., Lawlor, D. A., Lynch, J. W., & Davey Smith, G. (2006). Indicators of socioeconomic position (part 2). *Journal of Epidemiology & Community Health, 60*, 95-101.

Garcia-Bailo, B., Toguri, C., Eny, K. M., & El-Sohemy, A. (2009). Genetic variation in taste and its influence on food selection. *OMICS, 13*, 69-80.

Garcia, J., Ervin, F. R., & Koelling, R. A. (1966). Learning with prolonged delay of reinforcement. *Psychonomic Science, 5,* 121-122.

Gardiner, S. J. & Begg, E. J. (2006). Pharmacogenetics, drug-metabolizing enzymes, and clinical practice. *Pharmacological Reviews, 58*, 521-590.

Garrett, B. E. & Griffiths, R. R. (1998). Physical dependence increases the relative reinforcing effects of caffeine versus placebo. *Psychopharmacology, 139*, 195-202.

Gerrish, C. J. & Mennella, J. A. (2001). Flavor variety enhances food acceptance in formula-fed infants. *American Journal of Clinical Nutrition, 73*, 1080-1085.

Gibson, E. L., Kreichauf, S., Wildgruber, A., Vogele, C., Summerbell, C. D., Nixon, C., . . . Manios, Y. (2012). A narrative review of psychological and educational strategies applied to young children's eating behaviours aimed at reducing obesity risk. *Obesity Reviews, 13*, S85-95.

Gibson, E. L. & J. Wardle (2003). Energy density predicts preferences for fruit and vegetables in 4-year-old children. *Appetite, 41*, 97-98.

Gibson, E. L., Wardle, J., & Watts, C. J. (1998). Fruit and vegetable consumption, nutritional knowledge and beliefs in mothers and children. *Appetite, 31*, 205-228.

Gittelsohn, J., Wolever, T. M., Harris, S. B., Harris-Giraldo, R., Hanley, A. J., & Zinman, B. (1998). Specific patterns of food consumption and preparation are associated with diabetes and obesity in a Native Canadian community. *Journal of Nutrition, 128*, 541-547.

Graham, J. M., Guthrie, A. C., & Thompson, B. W. (2003). Consequences of not interpreting structure coefficients in published CFA research: a reminder. *Structural Equation Modeling: A Multidisciplinary Journal, 10*, 142-153.

Greene, L. S., Desor, J. A., & Maller, O. (1975). Heredity and experience - their relative importance in development of taste preference in man. *Journal of Comparative and Physiological Psychology, 89*, 279-284.

Greenhalgh, J., Dowey, A. J., Horne, P. J., Fergus Lowe, C., Griffiths, J. H., & Whitaker, C. J. (2009). Positive- and negative peer modelling effects on young children's consumption of novel blue foods. *Appetite, 52*, 646-653.

Grumbach, K., Coleman, B. G., Arger, P. H., Mintz, M. C., Gabbe, S. V., & Mennuti, M. T. (1986). Twin and singleton growth patterns compared using US. *Radiology, 158*, 237-241.

Grummer-Strawn, L. M., Scanlon, K. S., & Fein, S. B. (2008). Infant feeding and feeding transitions during the first year of life. *Pediatrics, 122*, S36-42.

Gunderson, E. R., Tsai, A. L., Selby, J. V., Caan, B., Mayer-Davis, E. J., & Risch, N. (2006). Twins of mistaken zygosity (TOMZ): Evidence for genetic contributions to dietary patterns and physiologic traits. *Twin Research and Human Genetics*, 9, 540-549.

Haines, L., Wan, K. C., Lynn, R., Barrett, T. G., & Shield, J. P. (2007). Rising incidence of type 2 diabetes in children in the U.K. *Diabetes Care, 30*, 1097-1101.

Haire-Joshu, D., Elliott, M. B., Caito, N. M., Hessler, K., Nanney, M. S., Hale, N., . . . Brownson, R. C. (2008). High 5 for Kids: the impact of a home visiting program on fruit and vegetable intake of parents and their preschool children. *Preventive Medicine, 47*, 77-82.

Hall, J. G. (2003). Twinning. *Lancet, 362*, 735-743.

Haller, R., Rummel, C., Henneberg, S., Pollmer, U., & Koster, E. P. (1999). The influence of early experience with vanillin on food preference later in life. *Chemical Senses, 24*, 465-467.

Hammond, J., Nelson, M., Chinn, S., & Rona, R. J. (1993). Validation of a food frequency questionnaire for assessing dietary-intake in a study of coronary heart-disease risk-factors in children. *European Journal of Clinical Nutrition, 47*, 242-250.

Hansen, J. L., Reed, D. R., Wright, M. J., Martin, N. G., & Breslin, P. A. (2006). Heritability and genetic covariation of sensitivity to PROP, SOA, quinine HCl, and caffeine. *Chemical Senses, 31*, 403-413.

Hardy, L. L., King, L., Kelly, B., Farrell, L., & Howlett, S. (2010). Munch and Move: evaluation of a preschool healthy eating and movement skill program. *International Journal of Behavioral Nutrition and Physical Activity, 7,* 80.

Harper, L. V. & Sanders, K. M. (1975). Effect of adults eating on young childrens acceptance of unfamiliar foods. *Journal of Experimental Child Psychology, 20*, 206-214.

Harris, G. (2008). Development of taste and food preferences in children. *Current Opinion in Clinical Nutrition and Metabolic Care, 11*, 315-319.

Harris, G., Thomas, A., & Booth, D. A. (1990). Development of salt taste in infancy. *Developmental Psychology, 26*, 534-538.

Hausner, H., Bredie, W. L. P., Mølgaard, C., Petersen, M. A., & Møller, P. (2008). Differential transfer of dietary flavour compounds into human breast milk. *Physiology & Behavior, 95*, 118-124.

Hausner, H., Nicklaus, S., Issanchou, S., Molgaard, C., & Moller, P. (2010). Breastfeeding facilitates acceptance of a novel dietary flavour compound. *Clinical Nutrition, 29*, 141-148.

Hausner, H., Olsen, A., & Moller, P. (2012). Mere exposure and flavour-flavour learning increase 2-3 year-old children's acceptance of a novel vegetable. *Appetite, 58*, 1152-1159.

Hausner, H., Philipsen, M., Skov, T., Petersen, M. A., & Bredie, W. L. P. (2009). Characterization of the volatile composition and variations between infant formulas and mother's milk. *Chemosensory Perception, 2*, 79-93.

Havermans, R. C. & A. Jansen (2007). Increasing children's liking of vegetables through flavour–flavour learning*. Appetite, 48*, 259-262.

He, F. J., Nowson, C. A., & MacGregor, G. A. (2006). Fruit and vegetable consumption and stroke - Reply. *Lancet, 367*, 1656-1656.

Health Survey for England (2008). *Health Survey for England 2007 Volume 1. Health lifestyles: knowledge, attitudes and behaviour.* The health and social care information centre. Retrieved from: http://.hscic.gov.uk/catalogue/PUB00415.

Hendy, H. M. (1999). Comparison of five teacher actions to encourage children's new food acceptance. *Annals of Behavioral Mededicine, 21,* 20-26.

Hendy, H. M. & B. Raudenbush (2000). Effectiveness of teacher modeling to encourage food acceptance in preschool children. *Appetite, 34*, 61-76.

Hendy, H. M., Williams, K. E., & Camise, T. S. (2005). "Kids Choice" school lunch program increases children's fruit and vegetable acceptance. *Appetite*, 45, 250-263.

Hepper, P. (1995). Human fetal olfactory learning. *International Journal of Prenatal and Perinatal Psychology, 7*, 147-151.

Hesketh, K. D. & K. J. Campbell (2010). Interventions to prevent obesity in 0-5 year olds: an updated systematic review of the literature. *Obesity, 18*, S27-35.

Hetherington, M. M., Pirie, L. M., & Nabb, S. (2002). Stimulus satiation: effects of repeated exposure to foods on pleasantness and intake. *Appetite, 38*, 19-28.

Hill, C., Wardle, J., & Cooke, L. (2009). Adiposity is not associated with children's reported liking for selected foods. *Appetite, 52*, 603-608.

Horne, P. J., Greenhalgh, J., Erjavec, M., Lowe, C. F., Viktor, S., & Whitaker, C. J. (2011). Increasing pre-school children's consumption of fruit and vegetables. A modelling and rewards intervention. *Appetite, 56*, 375-385.

Horne, P. J., Tapper, K., Lowe, C. F., Hardman, C. A., Jackson, M. C., & Woolner, J. (2004). Increasing children's fruit and vegetable consumption: a peer-modelling and rewards-based intervention. *European Journal of Clinical Nutrition*, 58, 1649-1660.

Howard, A. J., Mallan, K. M., Byrne, R., Magarey, A., & Daniels, L. A. (2012). Toddlers' food preferences. The impact of novel food exposure, maternal preferences and food neophobia. *Appetite, 59*, 818-825.

Hu, F. B. & W. C. Willett (2002). Optimal diets for prevention of coronary heart disease. *Journal of the American Medical Association, 288*, 2569-2578.

Huang, A. L., Chen, X., Hoon, M. A., Chandrashekar, J., Guo, W., Trankner, D., . . . Zuker, C. S. (2006). The cells and logic for mammalian sour taste detection. *Nature, 442*, 934-938.

Hutcheson, G. D. & Sofroniou, N. (1999). *The multivariate social scientist : introductory statistics using generalized linear models*. London, Sage Publications Ltd.

Infant Feeding Survey 2005 (2007). *Incidence, prevalence and duration of breast-feeding.* The Information Centre for Health and Social Care. Retrieved from http://.hscic.gov.uk/catalogue/PUB00619

Jacobi, C., Agras, W. S., Bryson, S., & Hammer, L. D. (2003). Behavioral validation, precursors, and concomitants of picky eating in childhood. *Journal of the American Academy of Child & Adolescent Psychiatry, 42*, 76-84.

Jacobi, C., Schmitz, G., & Agras, W. S. (2008). Is picky eating an eating disorder? *International Journal of Eating Disorders, 41*, 626-634.

Jansen, A. & N. Tenney (2001). Seeing mum drinking a 'light' product: is social learning a stronger determinant of taste preference acquisition than caloric conditioning? *European Journal of Clinical Nutrition, 55*, 418-422.

Jansen, P. W., Roza, S. J., Jaddoe, V. W. V., Mackenbach, J. D., Raat, H., Hofman, A., . . . Tiemeier, H. (2012). Children's eating behavior, feeding practices of parents and weight problems in early childhood: results from the population-based Generation R Study. *International Journal of Behavioral Nutrition and Physical Activity, 9*, 130.

Johnson, S. L., McPhee, L., & Birch, L. L. (1991). Conditioned preferences: young children prefer flavors associated with high dietary fat. *Physiology & Behavior, 50*, 1245-1251.

Jones, L. R., Steer, C. D., Rogers, I. S., & Emmett, P. M. (2010). Influences on child fruit and vegetable intake: sociodemographic, parental and child factors in a longitudinal cohort study. *Public Health Nutrition, 13*, 1122-1130.

Jones, R. and P. Elias (2005). CASCOT: Computer Assisted Coding Tool.

Jonsdottir, O. H., Thorsdottir, I., Hibberd, P. L., Fewtrell, M. S., Wells, J. C., Palsson, G. I., . . . Kleinman, R. E. (2012). Timing of the introduction of complementary foods in infancy: a randomized controlled trial. *Pediatrics,130*, 1038-1045.

Joshipura, K. J., Ascherio, A., Manson, J. E., Stampfer, M. J., Rimm, E. B., Speizer, F. E., . . . Willett, W. C. (1999). Fruit and vegetable intake in relation to risk of ischemic stroke. *Journal of the American Medical Association, 282*, 1233-1239.

Joshipura, K. J., Hu, F. B., Manson, J. E., Stampfer, M. J., Rimm, E. B., Speizer, F. E., . . . Willett, W. C. (2001). The effect of fruit and vegetable intake on risk for coronary heart disease. *Annals of Internal Medicine, 134*, 1106-1114.

Kaiser, H. F. (1960). The application of electronic-computers to factor-analysis. *Educational and Psychological Measurement, 20*, 141-151.

Kaminski, L. C., Henderson, S. A., & Drewnowski, A. (2000). Young women's food preferences and taste responsiveness to 6-n-propylthiouracil (PROP). *Physiology & Behavior, 68*, 691-697.

Kelder, S. H., Perry, C. L., Klepp, K. I., & Lytle, L. L. (1994). Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *American Journal of Public Health, 84*, 1121-1126.

Keller, K. L., Steinmann, L., Nurse, R. J., & Tepper, B. J. (2002). Genetic taste sensitivity to 6-n-propylthiouracil influences food preference and reported intake in preschool children. *Appetite, 38*, 3-12.

Keller, K. L. & B. J. Tepper (2004). Inherited taste sensitivity to 6-n-propylthiouracil in diet and body weight in children. *Obesity Research, 12*, 904-912.

Kendler, K. S., Neale, M. C., Kessler, R. C., Heath, A. C., & Eaves, L. J. (1993). A Test of the Equal-Environment Assumption in Twin Studies of Psychiatric-Illness. *Behavior Genetics*, 23, 21-27.

Kendler, K. S., Neale, M. C., Kessler, R. C., Heath, A. C., & Eaves, L. J. (1994). Parental treatment and the equal environment assumption in twin studies of psychiatric illness. *Psychological Medicine, 24*, 579-590.

Kern, D. L., McPhee, L., Fisher, J., Johnson, S., & Birch, L. L. (1993). The postingestive consequences of fat condition preferences for flavors associated with high dietary fat. *Physiology & Behavior, 54*, 71-76.

Kim, U. K., Jorgenson, E., Coon, H., Leppert, M., Risch, N., & Drayna, D. (2003). Positional cloning of the human quantitative trait locus underlying taste sensitivity to phenylthiocarbamide. *Science, 299*, 1221-1225.

Klump, K. L., Holly, A., Iacono, W. G., McGue, M., & Willson, L. E. (2000). Physical similarity and twin resemblance for eating attitudes and behaviors: a test of the equal environments assumption. *Behavior Genetics, 30*, 51-58.

Klump, K. L., Holly, A., Iacono, W. G., McGue, M., & Willson, L. E. (2000). Age differences in genetic and environmental influences on eating attitudes and behaviors in preadolescent and adolescent female twins. *Journal of Abnormal Psychology, 109*, 239-251.

Knaapila, A., Silventoinen, K., Broms, U., Rose, R. J., Perola, M., Kaprio, J., & Tuorila, H. M. (2011). Food neophobia in young adults: genetic architecture and relation to personality, pleasantness and use frequency of foods, and body mass index—a twin study. *Behavior Genetics, 41*, 512-521.

Knai, C., Pomerleau, J., Lock, K., & McKee, M. (2006). Getting children to eat more fruit and vegetables: a systematic review. *Preventive Medicine, 42*, 85-95.

Koh, G. A., Scott, J. A., Oddy, W. H., Graham, K. I., & Binns, C. W. (2010). Exposure to non-core foods and beverages in the first year of life: Results from a cohort study. *Nutrition & Dietetics, 67*, 137-142.

Koivisto, U., & Sjödén, P. (1996). Food and general neophobia in swedish families: parent-child comparisons and relationships with serving specific foods. *Appetite, 26*, 107-118.

Kramer, M. S., & Kakuma, R. (2002). The optimal duration of exclusive breastfeeding – A systematic review. *Geneva, Switzerland: World Health Organization. Retrieved from: http://.who.int/maternal_child_adolescent/documents/nhd_01_08/en/*

Kramer, M. S. & Kakuma, R. (2004). The optimal duration of exclusive breastfeeding: a systematic review. *Advances in Experimental Medicine & Biology, 554*: 63-77.

Kramer, M. S., & Kakuma, R. (2012). Optimal duration of exclusive breastfeeding. *Cochrane Database of Systematic Reviews, 8: CD 003517.*

Krondl, M., Coleman, P., Wade, J., & Milner, J. (1983). A twin study examining the genetic influence on food selection. *Human Nutrition – Applied Nutrition, 37*, 189-198.

Lakkakula, A. P., Zanovec, M., Silverman, L., Murphy, E., & Tuuri, G. (2008). Black children with high preferences for fuits and vegetables are at less risk of being at risk of overweight or overweight. *Journal of the American Dietetic Association, 108*, 1912-1915.

Lanfer, A., Knof, K., Barba, G., Veidebaum, T., Papoutsou, S., de Henauw, S., . . . Lissner, L. (2012). Taste preferences in association with dietary habits and weight status in European children: results from the IDEFICS study. *International Journal of Obesity, 36*, 27-34.

Laugerette, F., Passilly-Degrace, P., Patris, B., Niot, I., Montmayeur, J. P., & Besnard, P. (2006). CD36, a serious stake on track of the taste of fat. *Medecine Sciences, 22*, 357-359.

Launer, L. J., Forman, M. R., Hundt, G. L., Sarov, B., Chang, D., Berendes, H. W., & Naggan, L. (1992). Maternal recall of infant feeding events is accurate. *Journal of Epidemiology & Community Health, 46*, 203-206.

Legrand, L. N., McGue, M., & Iacono, W. G. (1999). A twin study of state and trait anxiety in childhood and adolescence. *Journal of Child Psychology & Psychiatry, 40*, 953-958.

Li, X., Staszewski, L., Xu, H., Durick, K., Zoller, M., & Adler, E. (2002). Human receptors for sweet and umami taste. *Proceedings of the National Academy of Sciences, 99*, 4692-4696.

Liem, D. G., Mars, M., & de Graaf, C. (2004). Consistency of sensory testing with 4- and 5-year-old children. *Food Quality and Preference, 15*, 541-548.

Liem, D. G. & Mennella, J. A. (2003). Heightened sour preferences during childhood. *Chemical Senses, 28*, 173-180.

Lien, N., Lytle, L. A., & Klepp, K. I. (2001). Stability in consumption of fruit, vegetables, and sugary foods in a cohort from age 14 to age 21. *Preventive Medicine, 33*, 217-226.

Lim, J., Urban, L., & Green, B. G. (2008). Measures of individual differences in taste and creaminess perception. *Chemical Senses, 33*, 493-501.

Liu, S., Manson, J. E., Lee, I. M., Cole, S. R., Hennekens, C. H., Willett, W. C., & Buring, J. E. (2000). Fruit and vegetable intake and risk of cardiovascular disease: the Women's Health Study. *American Journal of Clinical Nutrition, 72*, 922-928.

Llewellyn, C. (2011). *Genetic influences on appetite and weight in infancy*. (Unpublished doctoral dissertation). University College London, London, England.

Llewellyn, C. H., van Jaarsveld, C. H., Boniface, D., Carnell, S., & Wardle, J. (2008). Eating rate is a heritable phenotype related to weight in children. *American Journal of Clinical Nutrition, 88*, 1560-1566.

Llewellyn, C. H., van Jaarsveld, C. H., Johnson, L., Carnell, S., & Wardle, J. (2010). Nature and nurture in infant appetite: analysis of the Gemini twin birth cohort. *American Journal of Clinical Nutrition, 91*, 1172-1179.

Lock, K., Pomerleau, J., Causer, L., Altmann, D. R., & McKee, M. (2005). The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet. *Bulletin of the World Health Organization, 83*, 100-108.

Loehlin, J. C. & Nichols, R. C. (1976). *Heredity, environment and personality: a study of 850 sets of twins.* Austin, Texas: University of Texas Press.

Loewen, R. & Pliner, P. (1999). Effects of prior exposure to palatable and unpalatable novel foods on children's willingness to taste other novel foods. *Appetite, 32*, 351-366.

Logue, A. W., Logue, C. M., Uzzo, R. G., McCarty, M. J., & Smith, M. E. (1988). Food preferences in families. *Appetite, 10*, 169-180.

Lowe, C. F., Horne, P. J., Tapper, K., Bowdery, M., & Egerton, C. (2004). Effects of a peer modelling and rewards-based intervention to increase fruit and vegetable consumption in children. *European Journal of Clinical Nutrition*, 58, 510-522.

Ludy, M. J. & R. D. Mattes (2012). Comparison of sensory, physiological, personality, and cultural attributes in regular spicy food users and non-users. *Appetite, 58*, 19-27.

Lumeng, J. C., Cardinal, T. M., Sitto, J. R., & Kannan, S. (2008). Ability to taste 6-n-propylthiouracil and BMI in low-income preschool-aged children. *Obesity, 16*, 1522-1528.

Lytle, L. A., Seifert, S., Greenstein, J., & McGovern, P. (2000). How do children's eating patterns and food choices change over time? Results from a cohort study. *American Journal of Health Promotion, 14*, 222-228.

Maciel, S. M., Marcenes, W., Watt, R. G., & Sheiham, A. (2001). The relationship between sweetness preference and dental caries in mother/child pairs from Maringa-Pr, Brazil. *International Dental Journal, 51*, 83-88.

Magarey, A., Golley, R., Spurrier, N., Goodwin, E., & Ong, F. (2009). Reliability and validity of the Children's Dietary Questionnaire; a new tool to measure children's dietary patterns. *International Journal of Pediatric Obesity*, 4, 257-265.

Maier, A., Chabanet, C., Schaal, B., Issanchou, S., & Leathwood, P. (2007). Effects of repeated exposure on acceptance of initially disliked vegetables in 7-month old infants. *Food Quality and Preference, 18*, 1023-1032.

Maier, A., Chabanet, C., Schaal, B., Leathwood, P., & Issanchou, S. (2007). Food-related sensory experience from birth through weaning: Contrasted patterns in two nearby European regions. *Appetite, 49*, 429-440.

Maier, A. S., Chabanet, C., Schaal, B., Leathwood, P. D., & Issanchou, S. N. (2008). Breastfeeding and experience with variety early in weaning increase infants' acceptance of new foods for up to two months. *Clinical Nutrition, 27*, 849-857.

Maller, O. & J. A. Desor (1973). Effect of taste on ingestion by human newborns. *Symposium on Oral Senation & Perception*, 279-291.

Martin, N. G. (1975). Phenylthiocarbamide tasting in a sample of twins. *Annals of Human Genetics, 38*, 321-326.

Mascola, A. J., Bryson, S. W., & Agras, W. S. (2010). Picky eating during childhood: A longitudinal study to age 11 years. *Eating Behaviors, 11*, 253-257.

McClain, A. D., Chappuis, C., Nguyen-Rodriguez, S. T., Yaroch, A. L., & Spruijt-Metz, D. (2009). Psychosocial correlates of eating behavior in children and adolescents: a review. *International Journal of Behavioral Nutrition and Physical Activity, 6*, 54.

McCoy, N., & Zigler, E. (1965). Social reinforcer effectiveness as a function of the relationship between child and adult. *Journal of Personality and Social Psychology, 36*, 604-612.

McCrae, R. R., Costa, P. T., Jr., Terracciano, A., Parker, W. D., Mills, C. J., De Fruyt, F., & Mervielde, I. (2002). Personality trait development from age 12 to age 18: longitudinal, cross-sectional, and cross-cultural analyses. *Journal of Personality and Social Psychology, 83*, 1456-1468.

McFarlane, T., & Pliner, P. (1997). Increasing willingness to taste novel foods: effects of nutrition and taste information. *Appetite, 28*, 227-238.

McGowan, L., Croker, H., Wardle, J., & Cooke, L. J. (2012). Environmental and individual determinants of core and non-core food and drink intake in preschool-aged children in the United Kingdom. *European Journal of Clinical Nutrition, 66*, 322-328.

Mcgue, M., & Bouchard, T. J. (1984). Adjustment of twin data for the effects of age and sex. *Behavior Genetics, 14*, 325-343.

Mennella, J. A. (1995). Mother's milk: a medium for early flavor experiences. *Journal of Human Lactation, 11*, 39-45.

Mennella, J. A. (1996). Developmental changes in the acceptance of protein hydrolysate formula. *Journal of Developmental and Behavioral Pediatrics, 17*, 386-391.

Mennella, J. A., & Beauchamp, G. K. (1991). The transfer of alcohol to human milk. Effects on flavor and the infant's behavior. *New England Journal of Medicine, 325*, 981-985.

Mennella, J. A. & Beauchamp, G. K. (1993a). Beer, breast feeding, and folklore. *Developmental Psychobiology, 26*, 459-466.

Mennella, J. A. & Beauchamp, G. K. (1993b). The effects of repeated exposure to garlic-flavored milk on the nursling's behavior. *Pediatric Research, 34*, 805-808.

Mennella, J. A. & Beauchamp, G. K. (1996a). Developmental changes in the acceptance of protein hydrolysate formula. *Journal of Developmental & Behavioral Pediatrics, 17*, 386-391.

Mennella, J. A. & Beauchamp, G. K. (1996b). The human infants' response to vanilla flavors in mother's milk and formula. *Infant Behavior and Development, 19*, 13-19.

Mennella, J. A. & Beauchamp, G. K. (1998). Smoking and the flavor of breast milk. *New England Journal of Medicine, 339*, 1559-1560.

Mennella, J. A. & Beauchamp, G. K. (1999). Experience with a flavor in mother's milk modifies the infant's acceptance of flavored cereal. *Developmental Psychobiology, 35*, 197-203.

Mennella, J. A. & Beauchamp, G. K. (2002). Flavor experiences during formula feeding are related to preferences during childhood. *Early Human Development, 68*, 71-82.

Mennella, J. A., Forestell, C. A., Morgan, L. K., & Beauchamp, G. K. (2009). Early milk feeding influences taste acceptance and liking during infancy. *American Journal of Clinical Nutrition, 90*, 780s-788s.

Mennella, J. A., Jagnow, C. P., & Beauchamp, G. K. (2001). Prenatal and postnatal flavor learning by human infants. *Pediatrics, 107*, e88.

Mennella, J. A., Johnson, A., & Beauchamp, G. K. (1995). Garlic ingestion by pregnant women alters the odor of amniotic fluid. *Chemical Senses, 20*, 207-209.

Mennella, J. A., Lukasewycz, L. D., Castor, S. M., & Beauchamp, G. K. (2011). The timing and duration of a sensitive period in human flavor learning: a randomized trial. *The American Journal of Clinical Nutrition, 93*, 1019-1024.

Mennella, J. A., Nicklaus, S., Jagolino, A. L., & Yourshaw, L. M. (2008). Variety is the spice of life: strategies for promoting fruit and vegetable acceptance during infancy. *Physiology & Behavior, 94*, 29-38.

Mennella, J. A. & Trabulsi, J. C. (2012). Complementary foods and flavor experiences: setting the foundation. *Annals of Nutrition and Metabolism, 60*, 40-50.

Mennella, J. A., Ziegler, P., Briefel, R., & Novak, T. (2006). Feeding infants and toddlers study: the types of foods fed to Hispanic infants and toddlers. *Journal of the American Dietetic Association, 106*, S96-106.

Michaelsen, K. F., Larnkjær, A., Lauritzen, L., & Mølgaard, C. (2010). Science base of complementary feeding practice in infancy. *Current Opinion in Clinical Nutrition & Metabolic Care, 13*, 277-283

Mikula, G. (1989). Influencing food preferences of children by if-then type instructions. *European Journal of Social Psychology, 19*, 225-241.

Möller, L. M., de Hoog, M. L., van Eijsden, M., Gemke, R. J., & Vrijkotte, T. G. (2013). Infant nutrition in relation to eating behaviour and fruit and vegetable intake at age 5 years. *British Journal of Nutrition,* 109, 564-571.

Moore, A. P., Milligan, P., & Goff, L. M. (2012). An online survey of knowledge of the weaning guidelines, advice from health visitors and other factors that influence weaning timing in UK mothers. *Maternal & Child Nutrition*. e-pub ahead of print 19 June 2012.

Moore, L. L., Singer, M. R., Bradlee, M. L., Djousse, L., Proctor, M. H., Cupples, L. A., & Ellison, R. C. (2005). Intake of fruits, vegetables, and dairy products in early childhood and subsequent blood pressure change. *Epidemiology, 16*, 4-11.

Munro, B. H. (2005). *Statistical methods for health care research* (5th ed.). London: Lippincott Williams & Wilkins.

National Institute for Health and Clinical Excellence (2006). *Obesity : guidance on the prevention, identification, assessment and management of overweight and obesity in adults and children : quick reference guide 1 : for local authorities, schools and early years providers, workplaces and the public*. London, National Institute for Health and Clinical Excellence. Retrieved from http://.nice.org.uk/page.aspx?o=CG043QuickRefGuide

Neale, M. C., Boker, S. M., Xie, G., & Maes, H. H. (2003). *MX : statistical modeling* (6th ed.). Richmond, Department of Psychiatry.

Neale, M. C., & Maes, H. M. (2001). *Methodology for genetic studies of twins and families.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Ness, A. R., Maynard, M., Frankel, S., Smith, G. D., Frobisher, C., Leary, S. D., . . . Gunnell, D. (2005). Diet in childhood and adult cardiovascular and all-cause mortality: the Boyd Orr cohort. *Heart, 91*, 894-898.

Newman, J., & Taylor, A. (1992). Effect of a means end contingency on young childrens food preferences. *Journal of Experimental Child Psychology, 53*, 200-216.

Nicklaus, S. (2011). Children's acceptance of new foods at weaning. Role of practices of weaning and of food sensory properties. *Appetite, 57*, 812-815.

Nicklaus, S., Chabanet, C., Boggio, V., & Issanchou, S. (2005). Food choices at lunch during the third year of life: increase in energy intake but decrease in variety. *Acta Paediatrica, 94*, 1023-1029.

Norris, J. M., Barriga, K., Hoffenberg, E. J., Taki, I., Miao, D. M., Haas, J. E., . . . Rewers, M. (2005). Risk of celiac disease autoimmunity and timing of gluten introduction in the diet of infants at increased risk of disease. *Journal of the American Medical Association, 293*, 2343-2351.

North, K., & Emmett, P. (2000). Multivariate analysis of diet among three-year-old children and associations with socio-demographic characteristics. The Avon Longitudinal Study of Pregnancy and Childhood (ALSPAC) Study Team. *European Journal of Clinical Nutrition, 54*, 73-80.

Northstone, K., & Emmett, P. M. (2008). Are dietary patterns stable throughout early and mid-childhood? A birth cohort study. *British Journal of Nutrition, 100*, 1069-1076.

Norušis, M. J. (2012). IBM SPSS statistics 19 advanced statistical procedures companion. Upper Saddle River, NJ., Prentice Hall.

Nwaru, B. I., Erkkola, M., Ahonen, S., Kaila, M., Haapala, A.-M., Kronberg-Kippila, C., . . . Virtanen, S. M. (2010). Age at the introduction of solid foods during the first year and allergic sensitization at age 5 years. *Pediatrics, 125*, 50-59.

Office for National Statistics (2000a). Standard Occupational Classification 2000 (SOC 2000) Volume 1. Office for National Statistics. Newport.

Office for National Statistics (2000b). Standard Occupational Classification 2000 (SOC 2000) Volume 2. Office for National Statistics. Newport.

Office for National Statistics (2001). UK census data: Population pyramids. Newport.

Office for National Statistics (2003). Socio-economic classification of working-age population, summer 2003: Regional Trends 38. Newport.

Office for National Statistics (2005). National Statistics Socio-economic Classification: User Manual. Office for National Statistics. Newport. Retrieved from http://.ons.gov.uk/ons/guide-method/index.html

Office for National Statistics (2006a). Birth statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales. Newport.

Office for National Statistics (2006b). ONS Population report for England and Wales. Newport.

Office for National Statistics (2007). General Household Survey 2007, data for Great Britain in persons 16 and over. Newport.

Ong, K. K., & Loos, R. J. (2006). Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. *Acta Paediatrica, 95*, 904-908.

Parker, L., & Fox, A. (2001). The Peterborough Schools Nutrition Project: a multiple intervention programme to improve school-based eating in secondary schools. *Public Health Nutrition, 4*, 1221-1228.

Parsons, T. J., Power, C., Logan, S., & Summerbell, C. D. (1999). Childhood predictors of adult obesity: a systematic review. *International Journal of Obesity and Related Metabolic Diseases, 23*, S1-107.

Pasquet, P., Oberti, B., El Ati, J., & Hladik, C. M. (2002). Relationships between threshold-based PROP sensitivity and food preferences of Tunisians. *Appetite, 39*, 167-173.

Pearson, N., Biddle, S. J., & Gorely, T. (2009). Family correlates of fruit and vegetable consumption in children and adolescents: a systematic review. *Public Health Nutrition, 12*, 267-283.

Pelchat, M. L. & Pliner, P. (1995). Try it. You'll like it. Effects of information on willingness to try novel foods. *Appetite, 24*, 153-165.

Perez-Rodrigo, C., Ribas, L., Serra-Majem, L., & Aranceta, J. (2003). Food preferences of Spanish children and young people: the enKid study. *European Journal of Clinical Nutrition, 57*, S45-48.

Perry, C. L., Bishop, D. B., Taylor, G., Murray, D. M., Mays, R. W., Dudovitz, B. S., . . . Story, M. (1998). Changing fruit and vegetable consumption among children: the 5-a-Day Power Plus program in St. Paul, Minnesota. *American Journal of Public Health, 88*, 603-609.

Pliner, P. (1982). The effects of mere exposure on liking for edible substances. *Appetite, 3*, 283-290.

Pliner, P. (1994). Development of measures of food neophobia in children. *Appetite, 23*, 147-163.

Pliner, P. & Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite, 19*, 105-120.

Pliner, P. & Loewen, E. R. (1997). Temperament and food neophobia in children and their mothers. *Appetite, 28*, 239-254.

Pliner, P. & Melo, N. (1997). Food neophobia in humans: effects of manipulated arousal and individual differences in sensation seeking. *Physiology & Behavior, 61*, 331-335.

Pliner, P., Pelchat, M., & Grabski, M. (1993). Reduction of neophobia in humans by exposure to novel foods. *Appetite, 20*, 111-123.

Pliner, P., & Pelchat, M. L. (1986). Similarities in food preferences between children and their siblings and parents. *Appetite, 7*, 333-342.

Plomin, R., DeFries, J. C., McClearn, G. E., & McGuffin, P. (2008). *Behavioral genetics* (5th ed.). New York: Worth.

Poole, J. A., Barriga, K., Leung, D. Y. M., Hoffman, M., Eisenbarth, G. S., Rewers, M., & Norris, J. M. (2006). Timing of initial exposure to cereal grains and the risk of wheat allergy. *Pediatrics, 117*, 2175-2182.

Popkin, B. M. (2001). The nutrition transition and obesity in the developing world. *Journal of Nutrition, 131*, S871-S873.

Potts, H. W. & Wardle, J. (1998). The list heuristic for studying personality correlates of food choice behaviour: a review and results from two samples. *Appetite, 30*, 79-92.

Prescott, J., Soo, J., Campbell, H., & Roberts, C. (2004). Responses of PROP taster groups to variations in sensory qualities within foods and beverages. *Physiology & Behavior, 82*, 459-469.

Price, T. S., Freeman, B., Craig, I., Petrill, S. A., Ebersole, L., & Plomin, R. (2000). Infant zygosity can be assigned by parental report questionnaire data. *Twin Research, 3*, 129-133.

Pritchard, J. A. (1965). Deglutition by normal and anencephalic fetuses. *Obstetrics & Gynecology, 25,* 289-297.

Pronin, A. N., Xu, H., Tang, H., Zhang, L., Li, Q., & Li, X. (2007). Specific alleles of bitter receptor genes influence human sensitivity to the bitterness of aloin and saccharin. *Current Biology, 17*, 1403-1408.

Puhl, R. & Brownell, K. D. (2001). Bias, discrimination, and obesity. *Obesity Research, 9*, 788-805.

Rahmioğlu, N. & Ahmadi, K. R. (2010). Classical twin design in modern pharmacogenomics studies. *Pharmacogenomics, 11*, 215-226.

Rapley, G. & Murkett, T. (2008). *Baby-led weaning: helping your baby love good food.* London, Vermilion.

Rasmussen, M., Krolner, R., Klepp, K. I., Lytle, L., Brug, J., Bere, E., & Due, P. (2006). Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: Quantitative studies. *International Journal of Behavioural Nutrition & Physical Acitivity, 3,* 22.

Raudenbush, B., Van Der Klaauw, N. J., & Frank, R. A. (1995). The contribution of psychological and sensory factors to food preference patterns as measured by the Food Attitudes Survey (FAS). *Appetite, 25*, 1-15.

Reed, D. R. (2008). Birth of a new breed of supertaster. *Chemical Senses, 33*, 489-491.

Reed, D. R., Bachmanov, A. A., Beauchamp, G. K., Tordoff, M. G., & Price, R. A. (1997). Heritable variation in food preferences and their contribution to obesity. *Behavior Genetics, 27*, 373-387.

Reed, D. R., Tanaka, T., & McDaniel, A. H. (2006). Diverse tastes: genetics of sweet and bitter perception. *Physiology & Behaviour, 88*, 215-226.

Reilly, J. J., Ashworth, S., & Wells, J. C. (2005). Metabolisable energy consumption in the exclusively breast-fed infant aged 3--6 months from the developed world: a systematic review. *British Journal of Nutrition, 94*, 56-63.

Reilly, J. J. & Wells, J. C. (2005). Duration of exclusive breast-feeding: introduction of complementary feeding may be necessary before 6 months of age. *British Journal of Nutrition, 94*, 869-872.

Remington, A., Anez, E., Croker, H., Wardle, J., & Cooke, L. (2012). Increasing food acceptance in the home setting: a randomized controlled trial of parent-administered taste exposure with incentives. *American Journal of Clinical Nutrition, 95*, 72-77.

Resnicow, K., Davis-Hearn, M., Smith, M., Baranowski, T., Lin, L. S., Baranowski, J., . . . Wang, D. T. (1997). Social-cognitive predictors of fruit and vegetable intake in children. *Health Psychology, 16*, 272-276.

Reynolds, K. D., Baranowski, T., Bishop, D. B., Farris, R. P., Binkley, D., Nicklas, T. A., & Elmer, P. J. (1999). Patterns in child and adolescent consumption of fruit and vegetables: effects of gender and ethnicity across four sites. *Journal of the American College of Nutrition, 18*, 248-254.

Ricketts, C. D. (1997). Fat preferences, dietary fat intake and body composition in children. *European Journal of Clinical Nutrition, 51*, 778-781.

Rijsdijk, F. V. & Sham, P. C. (2002). Analytic approaches to twin data using structural equation models. *Briefings in Bioinformatics, 3*, 119-133.

Rimm, E. B., Ascherio, A., Giovannucci, E., Spiegelman, D., Stampfer, M. J., & Willett, W. C. (1996). Vegetable, fruit, and cereal fiber intake and risk of coronary heart disease among men. *Journal of the American Medical Association, 275*, 447-451.

Ritchey, N. & Olson, C. (1983). Relationships between family variables and children's preference for and consumption of sweet foods. *Ecology of Food and Nutrition, 13*, 257-266.

Rolls, B. J., Rowe, E. A., & Rolls, E. T. (1982a). How flavour and appearance affect human feeding. *Proceedings of the Nutrition Society, 41*, 109-117.

Rolls, B. J., Rowe, E. A., & Rolls, E. T. (1982b). How sensory properties of foods affect human feeding behavior. *Physiology & Behavior, 29*, 409-417.

Rosenstein, D. & Oster, H. (1988). Differential facial responses to four basic tastes in newborns. *Child Development, 59*, 1555-1568.

Rozin, P. (1976). The selection of food by rats, humans and other animals. In Rosenblatt, R., Hinde, C. Beer, C. & Shaw, E. (Eds.) *Advances in the study of behavior* (pp. 21-76). New York: Academic Press.

Rozin, P. (1991). Family resemblance in food and other domains: the family paradox and the role of parental congruence. *Appetite, 16*, 93-102.

Rozin, P., Gruss, L., & Berk, G. (1979). Reversal of innate aversions: attempts to induce a preference for chili peppers in rats. J*ournal of Comparative and Physiological Psychology, 93*, 1001-1014.

Rozin, P., & Kennel, K. (1983). Acquired preferences for piquant foods by chimpanzees. *Appetite, 4*, 69-77.

Rozin, P., & Millman, L. (1987). Family environment, not heredity, accounts for family resemblances in food preferences and attitudes: a twin study. *Appetite, 8*, 125-134.

Rozin, P., & Zellner, D. (1985). The role of Pavlovian conditioning in the acquisition of food likes and dislikes. *Annals of the New York Academy of Science, 443*: 189-202.

Russell, C. G., & Worsley, A. (2007). Do children's food preferences align with dietary recommendations? *Public Health Nutrition, 10*, 1223-1233.

Russell, C. G., & Worsley, A. (2008). A population-based study of preschoolers' food neophobia and its associations with food preferences. *Journal of Nutrition Education and Behavior, 40*, 11-19.

Russell, C. G., & Worsley, A. (2013). Why don't they like that? And can I do anything about it? The nature and correlates of parents' attributions and self-efficacy beliefs about preschool children's food preferences. *Appetite, 66*, 34-43.

Rydell, A. M., Dahl, M., & Sundelin, C. (1995). Characteristics of school children who are choosy eaters. *The Journal of Genetic Psychology, 156*, 217-229.

Santos, J. L., Ho-Urriola, J. A., Gonzalez, A., Smalley, S. V., Dominguez-Vasquez . . . Hodgson, M. I. (2011). Association between eating behavior scores and obesity in Chilean children. *Nutrition Journal*, *10,* 108.

Sargeant, L. A., Khaw, K. T., Bingham, S., Day, N. E., Luben, R. N., Oakes, S., . . . Wareham, N. J. (2001). Fruit and vegetable intake and population glycosylated haemoglobin levels: the EPIC-Norfolk Study. *European Journal of Clinical Nutrition, 55*, 342-348.

Scaglioni, S., Arrizza, C., Vecchi, F., & Tedeschi, S. (2011). Determinants of children's eating behavior. *American Journal of Clinical Nutrition, 94*, S2006-S2011.

Scarborough, P., Bhatnagar, P., Wickramasinghe, K. K., Allender, S., Foster, C., & Rayner, M. (2011). The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006-07 NHS costs. *Journal of Public Health, 33*, 527-535.

Scarr, S., & Cartersaltzman, L. (1979). Twin Method - Defense of a Critical Assumption. *Behavior Genetics, 9,* 527-542.

Schaal, B., Marlier, L., & Soussignan, R. (1998). Olfactory function in the human fetus: evidence from selective neonatal responsiveness to the odor of amniotic fluid. *Behavioral Neuroscience, 112*, 1438-1449.

Schaal, B., Marlier, L., & Soussignan, R. (2000). Human foetuses learn odours from their pregnant mother's diet. *Chemical Senses, 25*, 729-737.

Schrempft, S., van Jaarsveld, C. H. M., Fisher, A., & Wardle, J. (2013). Family and infant characteristics associated with timing of core and non-core food introduction in early childhood. *European Journal of Clinical Nutrition*, *67,* 652-657.

Schwartz, C., Chabanet, C., Laval, C., Issanchou, S., & Nicklaus, S. (2012). Breast-feeding duration: influence on taste acceptance over the first year of life. *British Journal of Nutrition,* 1-8.

Schwartz, C., Scholtens, P. A., Lalanne, A., Weenen, H., & Nicklaus, S. (2011). Development of healthy eating habits early in life. Review of recent evidence and selected guidelines. *Appetite, 57*, 796-807.

Sharma, K. (2008). Comparing sensory experience in bitter taste perception of phenylthiocarbamide within and between human twins and singletons: intrapair differences in thresholds and genetic variance estimates. *Anthropologischer Anzeiger, 66*, 211-224.

Shastry, B. S. (2005). Pharmacogenetics and the concept of individualized medicine. *Pharmacogenomics, 6*, 16-21.

Siega-Riz, A. M., Deming, D. M., Reidy, K. C., Fox, M. K., Condon, E., & Briefel, R. R. (2010). Food consumption patterns of infants and toddlers: where are we now? *Journal of the American Dietetic Association, 110*, S38-51.

Silventoinen, K., Kaprio, J., Lahelma, E., Viken, R. J., & Rose, R. J. (2003). Assortative mating by body height and BMI: Finnish twins and their spouses. *American Journal of Human Biology, 15*, 620-627.

Simonen, R., Levalahti, E., Kaprio, J., Videman, T., & Battie, M. C. (2004). Multivariate genetic analysis of lifetime exercise and environmental factors. *Medicine & Science in Sports & Exercise, 36*, 1559-1566.

Singer, M. R., Moore, L. L., Garrahie, E. J., & Ellison, R. C. (1995). The tracking of nutrient intake in young children: the Framingham Children's Study. *American Journal of Public Health, 85*, 1673-1677.

Singhal, A., Farooqi, I. S., O'Rahilly, S., Cole, T. J., Fewtrell, M., & Lucas, A. (2002). Early nutrition and leptin concentrations in later life. *American Journal of Clinical Nutrition, 75*, 993-999.

Singhal, A., Kennedy, K., Lanigan, J., Fewtrell, M., Cole, T. J., Stephenson, T., . . . Lucas, A. (2010). Nutrition in infancy and long-term risk of obesity: evidence from 2 randomized controlled trials. *American Journal of Clinical Nutrition, 92*, 1133-1144.

Skinner, J. D., Carruth, B. R., Bounds, W., Ziegler, P., & Reidy, K. (2002). Do food-related experiences in the first 2 years of life predict dietary variety in school-aged children? *Journal of Nutritional Education & Behavior, 34*, 310-315.

Skinner, J. D., Carruth, B. R., Wendy, B., & Ziegler, P. J. (2002). Children's food preferences: a longitudinal analysis. *Journal of the American Dietetic Association, 102*, 1638-1647.

Sleddens, E. F., Kremers, S. P., & Thijs, C. (2008). The children's eating behaviour questionnaire: factorial validity and association with Body Mass Index in Dutch children aged 6-7. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 49.

Smith, A. M., Roux, S., Naidoo, N. T., & Venter, D. J. (2005). Food choice of tactile defensive children. *Nutrition, 21*, 14-19.

Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysi : an introduction to basic and advanced multilevel modeling.* Los Angeles, Sage.

Spence, J. C., Carson, V., Casey, L., & Boule, N. (2011). Examining behavioural susceptibility to obesity among Canadian pre-school children: the role of eating behaviours. *International Journal of Pediatric Obesity, 6*, 501-507.

Sproston, K. and Primatesta, P. (2003) *Health Survey for England 2002: volume 1: the health of children and young people*, London: The Stationery Office.

Steiner, J. E. (1979). Human facial expressions in response to taste and smell stimulation. *Advances in Child Development & Behavior, 13*, 257-295.

Steinmetz, K. A. and J. D. Potter (1996). Vegetables, fruit, and cancer prevention: a review. *Journal of the American Dietetic Association, 96*, 1027-1039.

Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a measure of the motives underlying the selection of food: the food choice questionnaire. *Appetite, 25*, 267-284.

Stevens, J. P. (1996). *Applied multivariate statistics for the social sciences.* Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Stevenson, H. W., Keen, R., & Knights, R. M. (1963). Parents and strangers as reinforcing agents for children's performance. *Journal of Abnormal & Social Psychology, 67*, 183-186.

Sullivan, S. A., & Birch, L. L. (1990). Pass the sugar, pass the salt - experience dictates preference. *Developmental Psychology, 26*, 546-551.

Sullivan, S. A., & Birch, L. L. (1994). Infant dietary experience and acceptance of solid foods. *Pediatrics, 93*, 271-277.

Svensson, V., Lundborg, L., Cao, Y., Nowicka, P., Marcus, C., & Sobko, T. (2011). Obesity related eating behaviour patterns in Swedish preschool children and association with age, gender, relative weight and parental weight--factorial validation of the Children's Eating Behaviour Questionnaire. *International Journal of Behavioral Nutrition and Physical Activity, 8*, 134.

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics*. Boston: Allyn and Bacon.

Tarini, B. A., Carroll, A. E., Sox, C. M., & Christakis, D. A. (2006). Systematic review of the relationship between early introduction of solid foods to infants and the development of allergic disease. *Archives of Pediatrics & Adolescent Medicine, 160*, 502-507.

Tepper, B. J. (1999). Does genetic taste sensitivity to PROP influence food preferences and body weight? *Appetite, 32*, 422.

Tepper, B. J. (2008). Nutritional implications of genetic taste variation: the role of PROP sensitivity and other taste phenotypes. *Annual Reviews of Nutrition, 28*, 367-388.

Tepper, B. J., & Nurse, R. J. (1997). Fat perception is related to PROP taster status. *Physiology & Behavior, 61*, 949-954.

Tepper, B. J., White, E. A., Koelliker, Y., Lanzara, C., d'Adamo, P., & Gasparini, P. (2009). Genetic variation in taste sensitivity to 6-n-propylthiouracil and its relationship to taste perception and food selection. *Annals of the New York Academy of Science, 1170*, 126-139.

Tiger, L. (1992). *The pursuit of pleasure*. London: Little.

Tohill, B. (2005). Dietary intake of fruit and vegetables and management of body weight. World Health Organization; 2005. Retrieved from http://apps.who.int/iris/handle/10665/43145

Townsend, E., & Pitchford, N. J. (2012). Baby knows best? The impact of weaning style on food preferences and body mass index in early childhood in a case–controlled sample. *British Medical Journal Open*, 2, e000298

Trabulsi, J. C., & Mennella, J. A. (2012). Diet, sensitive periods in flavour learning, and growth. *International Review of Psychiatry, 24*, 219-230.

Tsuji, M., Nakamura, K., Tamai, Y., Wada, K., Sahashi, Y., Watanabe, K., . . . Nagata, C. (2012). Relationship of intake of plant-based foods with 6-n-propylthiouracil sensitivity and food neophobia in Japanese preschool children. *European Journal of Clinical Nutrution, 66*, 47-52.

Tylavsky, F. A., Holliday, K., Danish, R., Womack, C., Norwood, J., & Carbone, L. (2004). Fruit and vegetable intakes are an independent predictor of bone size in early pubertal children. *Americam Journal of Clinical Nutrition ,79*, 311-317.

Ullrich, N. V., Touger-Decker, R., O'Sullivan-Maillet, J., & Tepper, B. J. (2004). PROP taster status and self-perceived food adventurousness influence food preferences. *Journal of the American Dietetic Association, 104*, 543-549.

Van Cauwenberghe, E., Maes, L., Spittaels, H., van Lenthe, F. J., Brug, J., Oppert, J. M., & De Bourdeaudhuij, I. (2010). Effectiveness of school-based interventions in Europe to promote healthy nutrition in children and adolescents: systematic review of published and 'grey' literature. *British Journal of Nutrition, 103*, 781-797.

van Dommelen, P., de Gunst, M., van der Vaart, A., van Buuren, S., & Boomsma, D. (2008). Growth references for height, weight and body mass index of twins aged 0-2.5 years. *Acta Paediatrica, 97*, 1099-1104.

van Jaarsveld, C. H., Johnson, L., Llewellyn, C., & Wardle, J. (2010). Gemini: a UK twin birth cohort with a focus on early childhood weight trajectories, appetite and the family environment. *Twin Research & Human Genetics, 13*, 72-78.

van Jaarsveld, C. H., Llewellyn, C. H., Fildes, A., Fisher, A., & Wardle, J. (2012). Are my twins identical: parents may be misinformed by prenatal scan observations. *British Journal of Obsterics & Gynaecology, 119*, 517-518.

Vazquez, M., Pearson, P. B., & Beauchamp, G. K. (1982). Flavor preferences in malnourished Mexican infants. *Physiology & Behavior, 28*, 513-519.

Vereecken, C., Huybrechts, I., van Houte, H., Martens, V., Wittebroodt, I., & Maes, L. (2009). Results from a dietary intervention study in preschools Beastly Healthy at School. *International Journal of Public Health, 54*, 142-149.

Viana, V., Sinde, S., & Saxton, J. C. (2008). Children's eating behaviour questionnaire: associations with BMI in Portuguese children. *British Journal of Nutrition, 100*, 445-450.

Vickers, A. J., & Altman, D. G. (2001). Statistics notes: analysing controlled trials with baseline and follow up measurements. *British Medical Journal, 323*, 1123-1124.

Wang, J. C., Hinrichs, A. L., Bertelsen, S., Stock, H., Budde, J. P., Dick, D. M., . . . Goate, A. M. (2007). Functional variants in TAS2R38 and TAS2R16 influence alcohol consumption in high-risk families of African-American origin. *Alcoholism: Clinical & Experimental Research, 31*, 209-215.

Wardle, J., Carnell, S., Haworth, C. M., & Plomin, R. (2008). Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *American Journal of Clinical Nutrition, 87*, 398-404.

Wardle, J., & Cooke, L. (2008). Genetic and environmental determinants of children's food preferences. *British Journal of Nutrition, 99*, S15-21.

Wardle, J., Cooke, L. J., Gibson, E. L., Sapochnik, M., Sheiham, A., & Lawson, M. (2003). Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. *Appetite, 40*, 155-162.

Wardle, J., Guthrie, C., Sanderson, S., Birch, L., & Plomin, R. (2001). Food and activity preferences in children of lean and obese parents. *International Journal of Obesity and Related Metabolic Disorders, 25*, 971-977.

Wardle, J., Guthrie, C. A., Sanderson, S., & Rapoport, L. (2001). Development of the Children's Eating Behaviour Questionnaire. *Journal of Child Psychology & Psychiatry, 42*, 963-970.

Wardle, J., Herrera, M. L., Cooke, L., & Gibson, E. L. (2003). Modifying children's food preferences: the effects of exposure and reward on acceptance of an unfamiliar vegetable. *European Journal of Clinical Nutrition, 57*, 341-348.

Wardle, J., Sanderson, S., Guthrie, C. A., Rapoport, L., & Plomin, R. (2002). Parental feeding style and the inter-generational transmission of obesity risk. *Obesity Research, 10*, 453-462.

Wardle, J., Sanderson, S., Gibson, E. L., & Rapoport, L. (2001). Factor-analytic structure of food preferences in four-year-old children in the UK. *Appetite, 37*, 217-223.

Watt, R. G., Tull, K. I., Hardy, R., Wiggins, M., Kelly, Y., Molloy, B., . . . McGlone, P. (2009). Effectiveness of a social support intervention on infant feeding practices: randomised controlled trial. *Journal of Epidemiology & Community Health, 63*, 156-162.

Webber, L., Cooke, L., & Wardle, J. (2010). Maternal perception of the causes and consequences of sibling differences in eating behaviour. *European Journal of Clinical Nutrition, 64*, 1316-1322.

Webber, L., Hill, C., Saxton, J., Van Jaarsveld, C. H., & Wardle, J. (2009). Eating behaviour and weight in children. *International Journal of Obesity, 33*, 21-28.

Weber, W. W., & Hein, D. W. (1979). Clinical Pharmacokinetics of Isoniazid. *Clinical Pharmacokinetics, 4*, 401-422.

Wijlaars, L. P., Johnson, L., van Jaarsveld, C. H., & Wardle, J. (2011). Socioeconomic status and weight gain in early infancy. *Intnernational Journal of Obesity, 35*, 963-970.

Witt, K. E., & Dunn, C. (2012). Increasing fruit and vegetable consumption among preschoolers: evaluation of color me healthy. *Journal of Nutrition Education and Behavior, 44*, 107-113.

Wolfenden, L., Wyse, R. J., Britton, B. I., Campbell, K. J., Hodder, R. K., Stacey, F. G., . . . James, E. L. (2012). Interventions for increasing fruit and vegetable consumption in children aged 5 years and under. *Cochrane Database Systematic Reviews 11,* CD008552.

World Health Organization (1997). Diet, nutrition and the prevention of chronic diseases. *Technical Report Series, No. 797*. Geneva, Switzerland: World Health Organization. Retrieved from: http://who.int/dietphysicalactivity/publications/trs916/intro/en/

World Health Organization (2001). The Optimal Duration of Exclusive Breastfeeding. Report of an Expert Consultation. Geneva, Switzerland: World Health Organization. Retrieved from: http://.who.int/nutrition/publications/optimal_duration_of_exc_bfeeding_report_eng.pdf.

World Health Organization (2002). The World Health Report 2002 - Reducing Risks, promoting healthy life. Geneva, Switzerland: World Health Organization. Retrieved from: http://.who.int/whr/2002/en/

World Health Organization (2003). Diet, nutrition and the prevention of chronic diseases. Report of a joint FAO/ WHO Expert Consultation. *Technical Report Series, No. 916*. Geneva, Switzerland: World Health Organization. Retrieved from: http://.who.int/dietphysicalactivity/publications/trs916/en

World Health Organization (2006). WHO Child Growth Standards: Length/Height-for-Age, Weight-for-Age, Weight for- Length, Weight-for-Height and Body Mass Index-for-Age: Methods and Development. Geneva, Switzerland: World Health Organization. Retrieved from: http://who.int/childgrowth/standards/technical_report/en/

World Health Organization (2009). Global health risks: mortality and burden of disease attributable to selected major risks. Geneva, Switzerland: World Health Organization. Retrieved from: http://who.int/healthinfo/global_burden_disease/global_health_risks/en/

World Health Organization (2011). Global status report on noncommunicable diseases 2010. Geneva, Switzerland: World Health Organization. Retrieved from: http://www.who.int/nmh/publications/ncd_report2010/en/

Wosje, K. S., Khoury, P. R., Claytor, R. P., Copeland, K. A., Hornung, R. W., Daniels, S. R., & Kalkwarf, H. J. (2010). Dietary patterns associated with fat and bone mass in young children. *American Journal of Clinical Nutrition, 92*, 294-303.

Wright, C., & Birks, E. (2000). Risk factors for failure to thrive: a population-based survey. *Child Care, Health & Development, 26*, 5-16.

Wright, C. M., Williams, A. F., Elliman, D., Bedford, H., Birks, E., Butler, G., . . . Cole, T. J. (2010). Using the new UK-WHO growth charts. *British Medical Journal*, *340*, 647-655.

Wyse, R., Wolfenden, L., Campbell, E., Campbell, K. J., Wiggers, J., . . . Heard, T. R. (2012). A cluster randomized controlled trial of a telephone-based parent intervention to increase preschoolers' fruit and vegetable consumption. *American Journal of Clinical Nutrition, 96*, 102-110.

Yang, J., Lee, S. H., Goddard, M. E., & Visscher, P. M. (2011). GCTA: a tool for genome-wide complex trait analysis. *American Journal of Human Genetics, 88*, 76-82.

Yang, Z., & Huffman, S. L. (2013). Nutrition in pregnancy and early childhood and associations with obesity in developing countries. *Maternal & Child Nutrition, 9*, 105-119.

Yeomans, M. R. (2012). Flavour-nutrient learning in humans: an elusive phenomenon? *Physiology & Behavior, 106*, 345-355.

Yngve, A., Wolf, A., Poortvliet, E., Elmadfa, I., Brug, J., Ehrenblad, B., . . . Klepp, K. I. (2005). Fruit and vegetable intake in a sample of 11-year-old children in 9 European countries: The Pro Children cross-sectional survey. *Annals of Nutrition and Metabolism, 49*, 236-245.

Zeinstra, G. G., Koelen, M. A., Kok, F. J., & de Graaf, C. (2009). Children's hard-wired aversion to pure vegetable tastes. A 'failed' flavour-nutrient learning study. *Appetite, 52*, 528-530.

Zellner, D. A., Rozin, P., Aron, M., & Kulish, C. (1983). Conditioned enhancement of humans liking for flavor by pairing with sweetness. *Learning and Motivation, 14*, 338-350.

Zutavern, A., Brockow, I., Schaaf, B., von Berg, A., Diez, U., Borte, M., . . . Heinrich, J. (2008). Timing of solid food introduction in relation to eczema, asthma, allergic rhinitis, and food and inhalant sensitization at the age of 6 years: results from the prospective birth cohort study LISA. *Pediatrics, 121*, e44-52.

APPENDICES

Appendix 1. Gemini study materials

Appendix 1.1. Gemini first contact letter

gemini
health and development in twins

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

WELCOME TO GEMINI

Thank you for showing interest in our exciting new study: Gemini - which we are launching at UCL (University College London). You recently send a reply card back to the Office of National Statistics stating your interest in participating in this research. We are pleased to welcome you into Gemini.

Within the next few weeks, we are sending out the first questionnaires. We can also offer a web-based version if that is easy for you.

If you would like to fill out our web-based questionnaires we can send you the link by email. Please send us an email with your full name and postcode at Gemini@public-health.ucl.ac.uk indicating that you would like to receive the Gemini link and fill out questionnaires online.

If you prefer paper copies of questionnaires then you do not need to contact us; we will send you paper questionnaires and a pre-paid envelope (no stamp required) for easy return within the next few weeks.

If you have any queries about the study, please contact the Gemini team (Rebecca, Ellen, Clare or Laura) at 020 7679 6643 or send us an email at Gemini@public-health.ucl.ac.uk .

Kind regards,

Jane Wardle

Professor Jane Wardle

Appendix 1.2. Gemini baseline questionnaire letter

gemini
health and development in twins

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

Dear <<Name Mother>> Family ID Number: GEM<<FAM ID>>

Thank you for indicating your interest in our exciting new study: Gemini – health and development in twins. You recently sent a reply card back to the Office of National Statistics stating that you would like to participate in this research. We are pleased to welcome you into Gemini.

Together with this letter you will find two copies of the consent form. To confirm your interest in Gemini, we would like to ask you to initial all the boxes on the consent form and sign them, and send one copy back to us together with the questionnaires and keep one copy for yourself.

Questionnaires
We have divided our questions in to two booklets for your convenience. The questionnaires are about your twins' growth, eating and activity habits and your views on feeding. The questionnaires also include some questions about various aspects of your home and family life. The information you provide will remain completely confidential. The questionnaires shouldn't take very long to complete and are designed to allow you to answer questions section by section at your own leisure.

Can I fill out the questionnaires online?
Yes, the questionnaires are available on the internet. If you would like to fill out our web-based questionnaires instead of the paper-based ones, please go to the following webpage, and follow the instructions: http://www.attitudestohealth.co.uk/gemini/
Please note that questions are divided into two parts just like the paper-based questionnaires. Each part needs to be completed in one go; although it is possible to take short breaks (15 minutes) as long as you leave the web browser open. Once you have started part one you will not be able to save it and come back to it later. However, after completing part one you can come back and complete part two (in one go) at your convenience.

What do I need to send back?
After you have signed the consent form and answered all of the questions in the two booklets, you can send us the consent form and both booklets in the freepost envelope (no stamps required). If you completed the questionnaires online, then just send the signed consent form in the freepost envelope to: Gemini, Health Behaviour Research Centre, UCL, 2-16 Torrington Place, London WC1E 6BT.

When will I be contacted again?
We would like to contact you again when the twins are about 15 months old. You do not have to let us know now whether or not you would like to continue to participate. We will confirm this with you the next time we contact you.

If you have any queries about the study, please contact the Gemini team (Rebecca, Ellen, Clare or Laura) at 020 7679 6643 or send us an email at Gemini@public-health.ucl.ac.uk.

Kind regards,

Jane Wardle

Professor Jane Wardle

Appendix 1.3. Gemini consent form

gemini
health and development in twins

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

CONSENT FORM

Title of Project: Gemini – health and development in twins

Study Reference: 07/H0714/116 Family ID number:

Name of Researchers: *Professor Jane Wardle, Dr. Ellen van Jaarsveld*

Please initial box

1. I confirm that I have read and understood the information leaflet for the above study which I received with the invitation letter. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I confirm that I have had sufficient time to consider whether or not I want to be included in the study. ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐
4. I consent to the processing of my personal information for the purposes of this study, and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998. ☐
5. I agree to be contacted in the future by the Gemini team who would like to invite me to participate in follow-up studies. ☐
6. I understand that the information I have submitted will be published as a report. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications. ☐
7. I understand that some study documents may be looked at by responsible representatives from the Research & Development Unit, UCL to ensure that the study is being conducted properly. My identity will be protected at all times. ☐
8. I agree to take part in the above study. ☐

______________________ ______________________ ______________________
Name of Participant **Date** **Signature**

Name of Researcher: Jane Wardle **Date**: 23 / 07 / 2008 **Signature**: Jane Wardle

When completed: Please keep 1 copy for your own records; and send 1 copy back to:
Gemini, Health Behaviour Research Centre, UCL, 2-16 Torrington Place, London, WC1E 6BT

Appendix 1.4. Gemini participant information leaflet

Do I have to take part?
It is up to you to decide whether to take part. If you choose not to participate it will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to take part you have this information sheet to keep and you will be asked to sign a consent form. If you decide to take part now, you are still free to withdraw at any time without giving a reason.

How can I take part in Gemini?
If you are interested in taking part in Gemini, please fill out the reply slip and return it in the enclosed envelope to ONS.

The more families that agree to take part, the more valuable the study will be. The team looks forward to your response.

Who has approved this study?
This study has been reviewed and approved by Cancer Research UK and UCL/UCLH Research Ethics Committee.

Who is running the study?
Gemini is being conducted by the Health Behaviour Research Centre, which is part of University College London. The study has been financed by Cancer Research UK, because of their interest in healthy food choices.

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH
HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

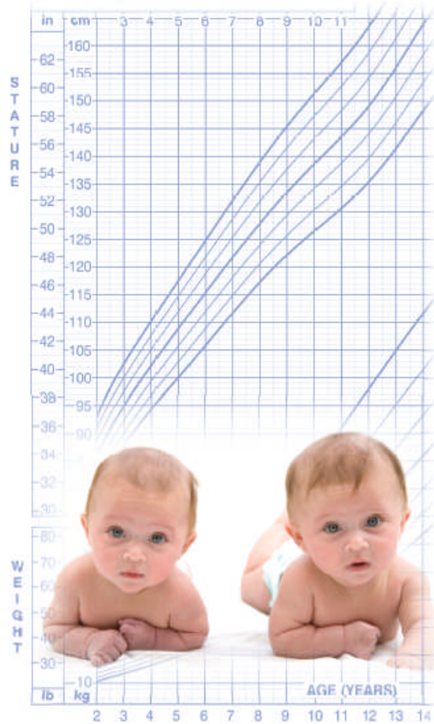
For further information, please contact us:

T 020 7679 6643
E Gemini@public-health.ucl.ac.uk

Professor Jane Wardle - Principal Investigator
Dr Ellen van Jaarsveld - Study Coordinator
Ms Clare Llewellyn - Researcher
Dr Laura Johnson - Researcher
Ms Rebecca Marlow - Administrative Assistant

gemini
health and development in twins

gemini
health and development in twins



Information leaflet

gemini

health and development in twins

We are inviting you to join our new research project - Gemini. We are asking you because you have had twins – congratulations! Twins are very special to their parents. They are also very interesting to researchers because studying them can tell us about how genes and environments work together.

You should only take part if you want to; choosing not to participate will not disadvantage you in any way. Before you decide, you should read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you want more information.

What is Gemini?

Gemini is a new national study following 2,400 parents and their twins through their first five years. We shall be interested in the twins' health, eating habits and activity with a main focus on appetite and weight gain. We are also interested in parents' attitudes and aspects of the home situation.

What does taking part involve?

Each year, we would like to send you questionnaires about your twins' development. A freepost envelope will be enclosed for easy return of the questionnaires. We can also offer a web-based version if that is easy for you. The information you provide will remain completely confidential. The questionnaire should take no longer than 90 minutes to complete.

Selecting families

The General Register Office (part of the Office for National Statistics or ONS) have identified your name as the mother of twins from their Birth Registration database. They are helping the Gemini study by contacting families with newborn twins. Names and addresses will only be made available to Gemini by ONS when parents have agreed to participate. Only families in England and Wales with registered twin births in 2007-2008 will be contacted.

Anticipated benefits to you and your family

Being part of Gemini should be interesting and fun! Families involved in an earlier study in which twins were followed from age 4 to 11 years have told us they enjoyed the experience.

One parent said, "I thought I would be too busy to do the study but I found it was an opportunity to stop and reflect about my twins and our life together as a family. It was time well spent!"

"I think it's great that my twins are part of the study and they think they're pretty special for being selected" said another parent.

"I've enjoyed reading the newsletter and read about some twins being very similar and others being totally different" said another parent.

Will the information I give remain confidential?

Yes. The privacy of the families and twins taking part in the study is strictly protected. All information collected about you and your child during the course of the research will be kept strictly confidential. The research team will not pass on your personal details to anyone else. Professional standards of confidentiality will be adhered to and all data will be collected and stored in accordance with the Data Protection Act 1998.

How will the information be used?

The information collected in the study will help us learn more about children's growth and health. It could also help the government to plan policies and services that benefit families and children. We will report our findings in academic and health-related journals and present them to relevant health professionals at meetings and conferences. You will not be identified in any reports or publications arising from the study.

Appendix 1.5. Gemini baseline questionnaire – part 1 (T0)

Family ID Number ☐☐☐☐☐☐

WELCOME TO

gemini

health and development in twins

Booklet 1 - You and Your Family

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
Gemini@public-health.ucl.ac.uk

HOW TO FILL IN THIS BOOKLET

Thank you for agreeing to fill out this booklet. Before you start, here is a bit of guidance:

- We realise that parents of twins are very busy! We are especially grateful.
- We know the questionnaire is quite long, but please try to answer *all* the questions you are asked. This will help us to get a full picture of you and your twins' circumstances.
- Please be as honest as you can when answering our questions. We want to know what you really think. Everything you tell us will be kept strictly confidential.
- This may sound obvious, but please write as clearly as possible. This will help us use all the valuable information you have provided.

Here is an example of how a question *could* be answered.

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

A1.	**Do you think your twins are identical or non-identical?**	Identical	☑	Non-identical	☐
	Why do you think this?	...The twins shared the same sac and placenta...			
A2.	**As your twins grow older, do you have more time for yourself?**	Yes	☑	No	☐

THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE <u>MOTHER</u> OF THE TWINS.
IF YOU ARE NOT THE MOTHER, PLEASE CONTACT US AND WE WILL
SEND YOU THE APPROPRIATE QUESTIONNAIRE

THANK YOU FOR YOUR TIME AND ASSISTANCE IN FILLING OUT THIS BOOKLET

2

YOUR TWINS

A1. **Are you the primary caregiver of the twins?** Yes ☐ No ☐

A2. **What is your first born twin's name?** ______________________

Is your first born twin a boy or a girl? Boy ☐ Girl ☐

What is his/her date of birth? _____ / _____ / _______
DD MM YYYY

A3. **What is your second born twin's name?** ______________________

Is your second born twin a boy or a girl? Boy ☐ Girl ☐

The next few questions are all about whether your twins are identical or non-identical. This section needs to be completed only if you have same sex twins (please note: non-identical twins are often called fraternal twins)

If your twins are opposite sex, please go straight to B1 on page 6

A4. **Have you ever been told by a health professional (e.g. doctor, nurse, consultant) that your twins are identical or non-identical?**

Yes, identical ☐ Yes, non-identical ☐ No ☐

If YES, why did they think this?______________________________________

____

A5. **Do you think your twins are identical or non- identical?**

Identical ☐ Non-identical ☐

Why do you think this is? ______________________________________

____

3

A6. As your twins have grown older, has the likeness between them:

Become less ☐ Remained the same ☐ Become more ☐

A7. When looking at the twins:

	None	Only slight difference	Clear difference
Are there differences in the shade of your twins' hair?	☐	☐	☐
Are there differences in the texture of your twins' hair (fine or coarse, straight or curly etc)?	☐	☐	☐
Are there differences in the colour of your twins' eyes?	☐	☐	☐
Are there differences in the shape of your twins' ear lobes?	☐	☐	☐

A8. Have either of your twins' teeth begun to come through? Yes ☐ No ☐

If yes, was it at about the same time?

Yes, the twins had matching teeth on the same side come through within a few days of each other ☐

Yes, the twins had matching teeth on opposite sides come through within a few days of each other ☐

Yes, the twins had different teeth come through within a few days of each other ☐

No, the twins' first teeth did not come through within a few days of each other ☐

A9. Do you know your twins' ABO blood group and Rhesus (Rh) factors?

Yes ☐ No ☐

If YES, what are they? (please tick a blood group and rhesus factor for each twin)

	Blood group: A	B	AB	O	Rhesus factor: Rh+	Rh-
1st born	☐	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐	☐

4

A10. When looking at a new photograph of your twins, can you tell them apart (without looking at their clothes or using any other clues)?

Yes, easily	Yes, but it is hard sometimes	No, I often confuse them in photographs
☐	☐	☐

A11. Do any of the following people ever mistake your twins for each other?

	Yes, often	Yes, sometimes	Rarely or never	Not applicable
Your partner / husband	☐	☐	☐	☐
Older brothers or sisters	☐	☐	☐	☐
Other relatives	☐	☐	☐	☐
Babysitter or day carer	☐	☐	☐	☐
Close friends	☐	☐	☐	☐
Casual friends	☐	☐	☐	☐
People meeting the twins for the first time	☐	☐	☐	☐

A12. If the twins are ever mistaken for one another, does this ever happen when they are together?

Yes, often	Yes, sometimes	No, almost never	They are not mistaken for one another
☐	☐	☐	☐

A13. Would you say that your twins:

Are as physically alike as "two peas in a pod" (virtually the same)	☐
Are as physically alike as brothers and sisters are	☐
Do not look very much alike at all	☐

ABOUT YOU

B1. What is your date of birth? ____ / ____ / ______
DD MM YYYY

B2. In general, would you say your own health is:

Excellent	Very good	Good	Fair	Poor
☐	☐	☐	☐	☐

B3. About how tall are you?

______ centimetres (cms) OR ______ feet (ft) and ______ inches

B4. About how much do you weigh? If possible, use weighing scales for current weights, otherwise please give estimates

______ kilograms (kgs) OR ______ stones (st) and ______ pounds (lbs)

B5. Given your age and height, would you say that you are:

Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
☐	☐	☐	☐	☐

B6. Do you have any educational qualifications? (please tick <u>all</u> that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ______________________________

B7. Do you currently have a job?

On maternity leave	Yes, full-time	Yes, part-time	No	Stay at home to look after the children
☐	☐	☐	☐	☐

If NO, or stay at home to look after children please go straight to B9 on page 7

B8. What is your FULL job title? (please describe) ______________________________

Do you need any special qualifications for your job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe: ______________________________

____

B9. What is your ethnic group? Tick the appropriate box to indicate your cultural background

White	Black	Asian	Mixed	Chinese or any other
White British ☐	Caribbean ☐	Indian ☐	White and Black Caribbean ☐	Chinese ☐
		Pakistani ☐	White and Black African ☐	
White Irish ☐	African ☐			
		Bangladeshi ☐	White and Asian ☐	
Other White background ☐ (please specify) ________	Other Black background ☐ (please specify) ________	Other Asian background ☐ (please specify) ________	Other Mixed background ☐ (please specify) ________	Any other ☐ (please specify) ________

B10. Do you smoke cigarettes at all nowadays? Yes ☐ No ☐

If Yes, how many cigarettes a day do you usually smoke? ____ cigarettes per day

B11. Do you usually participate in the following activities? If so, how many times per week and for how long? (Write 0 if you do not participate in any activity)

Strenuous exercise (heart beats rapidly) i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling	____ times per week	____ minutes per session
Moderate exercise (not exhausting) i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing	____ times per week	____ minutes per session
Mild exercise (minimal effort) i.e. yoga, fishing from river bank, bowling, golf, easy walking	____ times per week	____ minutes per session

B12. In the last week about how many servings of .... did you eat?

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

B13. What is your marital status?

Married or cohabiting	Divorced	Widowed	Separated	Single
☐	☐	☐	☐	☐

If you are not married or cohabiting, please go to straight to D1 on page 10

7

ABOUT THE PERSON YOU LIVE WITH
(i.e. your husband or partner)

C1. What is your partner's relationship to the twins?

Natural father of the twins ☐ Legal guardian of the twins ☐ Other ☐

If other, please describe: ______________________

C2. What is your partner's date of birth? ____ / ____ / ______
DD MM YYYY

C3. About how tall is your partner?

______ centimetres (cms) OR ______ feet (ft) and ______ inches

C4. About how much does your partner weigh? If possible, use weighing scales for current weights, otherwise please give estimates

______ kilograms (kgs) OR ______ stones (st) and ______ pounds (lbs)

C5. Does your partner have any educational qualifications? (please tick <u>all</u> that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ______________________

C6. Does your partner currently have a job?

Yes, full-time	Yes, part-time	No	Stay at home to look after the children
☐	☐	☐	☐

If NO, or stay at home to look after children, please go straight to C8 on page 9

C7. What is your partner's FULL job title? (please describe) ______________________

Are there any special qualifications needed for their job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe: ______________________

8

C8. What is your partner's ethnic group? Tick the appropriate box to indicate your partner's cultural background

White	Black	Asian	Mixed	Chinese or any other
White British ☐	Caribbean ☐	Indian ☐	White and Black Caribbean ☐	Chinese ☐
		Pakistani ☐	White and Black African ☐	
White Irish ☐	African ☐			
		Bangladeshi ☐	White and Asian ☐	
Other White background ☐ (please specify) ____	Other Black background ☐ (please specify) ____	Other Asian background ☐ (please specify) ____	Other Mixed background ☐ (please specify) ____	Any other ☐ (please specify) ____

C9. Does your partner smoke cigarettes at all nowadays? Yes ☐ No ☐

If Yes, how many cigarettes a day does your partner usually smoke? ____ cigarettes per day

C10. Does your partner usually participate in the following activities? If so, how many times per week and for how long? (Write 0 if your partner does not participate in any activity)

Strenuous exercise (heart beats rapidly) i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling	____ times per week	____ minutes per session
Moderate exercise (not exhausting) i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing	____ times per week	____ minutes per session
Mild exercise (minimal effort) i.e. yoga, fishing from river band, bowling, golf, easy walking	____ times per week	____ minutes per session

C11. In the last week about how many servings of .... did your partner eat?

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

9

ABOUT OTHER CHILDREN IN THE HOME

D1. How many other children live in the home with your twins? (please write number)

__________ children

If there are no other children living in the home, please go straight to E1 on page 11

D2. Please tell us about all the children who live in the home with the twins:

Child's name	Date of birth	Sex		Does the child have the same mother as the twins?		Does the child have the same natural father as the twins?	
		Boy	Girl	Yes	No	Yes	No
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐
____________	____/____/_____ DD MM YYYY	☐	☐	☐	☐	☐	☐

If there are more than six other children or if there is anything else you would like to tell us about your family, please tell us in the open space below

YOUR PREGNANCY WITH THE TWINS

E1. About how much weight did you gain during your pregnancy with the twins?

______ kilograms (kgs) OR ____ stones (st) and ____ pounds (lbs)

E2. When you became pregnant with the twins, were you having any fertility treatment? Yes ☐ No ☐

If YES, please describe: ____________________

E3. Were you regularly taking any medicine whilst pregnant? Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

Please describe the type of medication: ____________________

E4. Did you smoke any cigarettes whilst pregnant? Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

How many cigarettes a day did you smoke, on average?
(write 0 if you smoked no cigarettes whilst pregnant) _______ cigarettes per day

E5. Did you drink any alcohol whilst pregnant? Yes ☐ No ☐

If YES, was this: (please tick all that apply) For first 3 months ☐ For middle 3 months ☐ For last 3 months ☐

How many units of alcohol did you drink per week, on average?
(1 unit = 1 glass of wine, or 1 measure of spirits, or ½ a pint of beer)
(write 0 if you drank no alcohol whilst pregnant) _______ units per week

E6. Did you experience any severe stress during your pregnancy (e.g. bereavement, serious illness in the family or major money problems)? Yes ☐ No ☐

If YES, please describe: ____________________

____

11

E7. During your pregnancy did you experience any of the following:

	Yes	No	Unsure
Morning sickness	☐	☐	☐
High blood pressure (pregnancy induced / gestational)	☐	☐	☐
Diabetes (pregnancy induced / gestational)	☐	☐	☐
Toxaemia / pre-eclampsia	☐	☐	☐
Vaginal bleeding	☐	☐	☐
Anaemia / iron deficiency	☐	☐	☐
Rubella / German Measles	☐	☐	☐
Slow growth of baby / babies	☐	☐	☐
Other serious pregnancy related problem (please describe)	☐	☐	☐

____

____

E8. Did <u>you</u> experience any physical or mental health problem in the first 6 months after birth; and were any of those problems diagnosed by a doctor?

Yes, diagnosed by a doctor ☐ Yes, but <u>not</u> diagnosed by a doctor ☐ No ☐

If YES, please describe: ____

____

E9. Have you ever been diagnosed with heart disease or diabetes, before or after your pregnancy?

	Yes	No	Unsure
Heart disease	☐	☐	☐
Diabetes (unrelated to pregnancy)	☐	☐	☐

E10. In their lives, have any family members ever been diagnosed with heart disease or diabetes?

	Father of twins	Brother or sister of twins	Your mother	Your father	Mother of the twins' father	Father of the twins' father	None
Heart disease	☐	☐	☐	☐	☐	☐	☐
Diabetes	☐	☐	☐	☐	☐	☐	☐

E11. In general, how would you describe the weights of your family members throughout their lives?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight	Unsure
Father of the twins	☐	☐	☐	☐	☐	☐
Your mother	☐	☐	☐	☐	☐	☐
Your father	☐	☐	☐	☐	☐	☐
Mother of the twins' father	☐	☐	☐	☐	☐	☐
Father of the twins' father	☐	☐	☐	☐	☐	☐

THE TWINS' BIRTH

F1. **How many weeks pregnant were you at the time of delivery?** __________ weeks

F2. **Was the birth by Caesarean section?**

Yes	No	Unsure
☐	☐	☐

If YES, why? ____

____

F3. **Approximately how long was the gap between the births?**

_______ hours OR ________ minutes

F4. **Did transfusion between twins occur (twin to twin transfusion syndrome)?**

Yes	No	Unsure
☐	☐	☐

F5. **Did your babies get a blood transfusion soon after birth?**

Yes	No	Unsure
☐	☐	☐

F6. **Were there any other complications or concerns about either twin at birth?**

	Yes	No	Unsure
1st born	☐	☐	☐
2nd born	☐	☐	☐

If Yes in 1st born, please describe: ____

____

____

____

If Yes in 2nd born, please describe: ____

____

____

____

13

F7. Did either of the twins have any special care after birth (e.g. incubators)?

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If Yes in 1st born, please describe: ____________________

____

If Yes in 2nd born, please describe: ____________________

____

F8. If yes, how long did they stay in special care?

1st born _____ days or _____ weeks

2nd born _____ days or _____ weeks

F9. How long did the twins stay in hospital after birth?

1st born _____ days or _____ weeks

2nd born _____ days or _____ weeks

F10. Do either of your twins have:

	Yes, 1st born	Yes, 2nd born	Neither
Physical problems (e.g. cleft lip, hole in the heart)	☐	☐	☐

If Yes in 1st born, please describe: ____________________

If Yes in 2nd born, please describe: ____________________

	Yes, 1st born	Yes, 2nd born	Neither
Genetic or chromosomal problems (e.g. Down's Syndrome, PKU)	☐	☐	☐

If Yes in 1st born, please describe: ____________________

If Yes in 2nd born, please describe: ____________________

	Yes, 1st born	Yes, 2nd born	Neither
Any other medical problem after birth	☐	☐	☐

If Yes in 1st born, please describe: ____________________

____

If Yes in 2nd born, please describe: ____________________

____

F11. Sometimes it is difficult to start feeding due to birth-related complications or other medical problems. Straight after birth, did either of your twins experience any complications which made it difficult to start feeding?

Yes, in 1st born ☐ Yes, in 2nd born ☐ No ☐

If Yes in 1st born, please describe: ______________________

____

If Yes in 2nd born, please describe: ______________________

____

F12. Were there any other times when feeding your twins was difficult, e.g. due to illness of the twins, health problems of parent, changes in jobs or moving house.

Yes, in 1st born ☐ Yes, in 2nd born ☐ No ☐

If Yes, please describe for each twin: (Use the back of the questionnaire if you need extra space)

Problem 1 in 1st born ______________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 2 in 1st born ______________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 1 in 2nd born ______________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

Problem 2 in 2nd born ______________________

At which ages did this influence your twins eating? __to__ weeks or __to__ months

15

THE TWINS' ILLNESSES AND ACCIDENTS

F13. About how many times have your babies seen the doctor due to illness or accidents since birth?

	Number of visits
1st born	________
2nd born	________

F14. Since birth, have your babies been admitted to hospital?

	No	Yes, once	Yes, more than once (write number)
1st born	☐	☐	________
2nd born	☐	☐	________

F15. Please briefly describe each hospital admission (Use the back of the questionnaire if you need more space)

	Age of twin (months)	Number of hospital nights	Reason for admission:
1st born	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
2nd born	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________
	______	______	______________________________

16

SOME FINAL QUESTIONS ABOUT YOU AND YOUR FAMILY

G1. What is the main language spoken in the home?

English ☐ Other (please specify) ______________________

G2. Altogether, how many adults live in the same house as the twins (including yourself)?

One ☐ Two ☐ Three ☐ Four or more: ______ (please give number)

G3. How many bedrooms does your household have, including bedsitting rooms and spare rooms?

One ☐ Two ☐ Three ☐ Four or more: ______ (please give number)

G4. How many cars or vans are normally available for use by you or any members of your household?

None ☐ One ☐ Two ☐ Three or more: ______ (please give number)

G5. Do you currently own or rent the accommodation you live in?

Own without mortgage ☐ Own with mortgage ☐ Rent privately ☐ Rent from local authority ☐

G6. Thinking of the income of the household as a whole, which category represents the <u>total</u> income of your <u>whole household</u> before deduction from income tax, National Insurance etc.

Up to £15,000 per year	☐	Between £52,500 and £60,000 per year	☐
Between £15,000 and £22,500 per year	☐	Between £60,000 and £67,500 per year	☐
Between £22,500 and £30,000 per year	☐	Between £67,500 and £75,000 per year	☐
Between £30,000 and £37,500 per year	☐	Between £75,000 and £82,500 per year	☐
Between £37,500 and £45,000 per year	☐	Between £82,500 and £90,000 per year	☐
Between £45, 000 and £52,500 per year	☐	More than £90,000 per year	☐

G7. Do you feel your family income is enough?

More than enough ☐ Enough ☐ Not enough ☐

G8. Please give the date on which you completed this booklet? ___ / ____ / ____ day/month/year

Please continue with BOOKLET 2 to tell us more about your twins

17

Thank you

for filling out this booklet.

PLEASE continue with BOOKLET 2 to tell us more about your twins

Space for any additional comments you would like to make :

18

Space for any additional comments you would like to make :

19

Appendix 1.6. Gemini baseline questionnaire – part 2 (T0)

Family ID Number ☐☐☐☐☐☐

WELCOME TO

gemini

health and development in twins

Booklet 2 - Your Twins

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
gemini@public-health.ucl.ac.uk

HOW TO FILL IN THIS BOOKLET

Thank you for agreeing to fill out this booklet. Before you start, here is a bit of guidance:

- We realise that parents of twins are very busy! We are especially grateful.
- We know the questionnaire is quite long, but please try to answer *all* the questions you are asked. This will help us to get a full picture of you and your twins' circumstances.
- Please be as honest as you can when answering our questions. We want to know what you really think. Everything you tell us will be kept strictly confidential.
- This may sound obvious, but please write as clearly as possible. This will help us use all the valuable information you have provided.

Here is an example of how a question *could* be answered.

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

A1.	**Do you think your twins are identical or non-identical?**	Identical	☑	Non-identical	☐
	Why do you think this?	...The twins shared the same sac and placenta...			
A2.	**As your twins grow older, do you have more time for yourself?**	Yes	☑	No	☐

THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE <u>MOTHER</u> OF THE TWINS.
IF YOU ARE NOT THE MOTHER, PLEASE CONTACT US AND WE WILL SEND YOU THE APPROPRIATE QUESTIONNAIRE

THANK YOU FOR YOUR TIME AND ASSISTANCE IN FILLING OUT THIS BOOKLET

2

YOUR TWINS' GROWTH

First we would like to learn a bit more detail about your twins' growth. This information may be in your child's health record (little red book) or you may have kept your own records.

A1. What were the lengths of the twins at birth and around 6 weeks?

	1st born	2nd born
At birth	_____ cm or _____ inches	_____ cm or _____ inches
Around 6 weeks	_____ cm or _____ inches	_____ cm or _____ inches

A2. What were the head circumferences of the twins?

	1st born	2nd born
At birth	_____ cm or _____ inches	_____ cm or _____ inches
Around 6 weeks	_____ cm or _____ inches	_____ cm or _____ inches

A3. What were the weights of the twins?

	1st born	2nd born
At birth	_____ kg or ____ lbs ___ oz	_____ kg or ____ lbs ___ oz
Around 6 weeks	_____ kg or ____ lbs ___ oz	_____ kg or ____ lbs ___ oz

A4. Please add other weight measurements below together with the date they were taken. Use the back of the questionnaire if you need extra space. Alternatively you can send us a photocopy of the relevant pages from your twins' health records (little red book)

Date measured	1st born				2nd born				These measurements came from…		
	kg		lbs,	oz	Kg		lbs,	oz	Health professional / health record		Own measure-ments
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐
__/__/____ DD MM YYYY	_____	or	___	___	_____	or	___	___	☐	or	☐

3

Some parents worry about their babies being underweight or overweight for their age and sex. The following questions explore this in a bit more detail

A5. How would you describe your baby's weight at the moment?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A6. Have you ever been concerned that your baby wasn't gaining enough weight? (tick all that apply)

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If No, please go straight to A8 on page 5

If yes, how old was your baby when you were concerned?

	0 - 3 months	4-6 months	7-9 months	10-12 months	Older than 1 year
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A7. How concerned are you that your baby is underweight at the moment?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

If you are concerned about either baby being underweight, why is this? (please tick the most important reasons)

	1st born	2nd born
The health visitor/doctor advised me my baby is not gaining enough weight	☐	☐
Low centile on growth chart	☐	☐
My baby doesn't look as big as other babies of the same age and sex	☐	☐
My baby lost weight recently	☐	☐
My baby has always had a low weight	☐	☐
My baby is not feeding well	☐	☐
Family member(s) think my baby is not heavy enough. If so, who?__________	☐	☐
Other reason. If so, what? ______________________________	☐	☐

4

A8. **Have you ever been concerned that your baby was gaining too much weight?**

	Yes	No
1st born	☐	☐
2nd born	☐	☐

If No, please go straight to B1 on page 6

If yes, how old was your baby when you were concerned?

	0 - 3 months	4-6 months	7-9 months	10-12 months	Older than 1 year
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

A9. **How concerned are you that your baby is overweight at the moment?**

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

If you are concerned about either baby being overweight, why is this? (please tick the most important reasons)

	1st born	2nd born
The health visitor/doctor advised me my baby is gaining too much weight	☐	☐
High centile on growth chart	☐	☐
My baby looks bigger than other babies of the same age and sex	☐	☐
My baby gained weight recently	☐	☐
My baby has always had a high weight	☐	☐
My baby is feeding very vigorously	☐	☐
Family member(s) think my baby is too heavy. If so, who?________________	☐	☐
Other reason. If so, what?____	☐	☐

____

YOUR FEEDING ROUTINE

Parents feed their babies in different ways, and we are interested in learning more about how you feed your twins. In the following questions, please think back to your twins' first three months of life

B1. Which of the following best describes each of your twins' eating routine during their first three months?

	I fed my baby whenever he/she cried, got fussy or seemed hungry	My baby was on a flexible feeding schedule (e.g. about every 3-4 hours)	My baby was on a rigid feeding schedule (e.g. I woke him/her up to eat on time)
1st born	☐	☐	☐
2nd born	☐	☐	☐

B2. Did you or the babies decide how often they should feed?

	Me only	Mostly me	Me and my baby equally	Mostly my baby	My baby only
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B3. Did you or the babies decide how much milk they should take in a feed?

	Me only	Mostly me	Me and my baby equally	Mostly my baby	My baby only
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B4. How would you classify your 'feeding philosophy' for each twin during their first three months?

	Feeding on demand (e.g. fed baby when he/she cried)	Feeding on a schedule (e.g. fed baby at set times)
1st born	☐	☐
2nd born	☐	☐

Now we would like to know more about how your feeding patterns have changed over time

By '**breastfeeding**', we mean any method of feeding breast milk, i.e. feeding directly from breast or giving expressed breast milk in a bottle

By '**bottle-feeding**', we mean feeding formula milk using a bottle

6

B5. Which feeding methods did you use in the first three months?

	1st born	2nd born
Entirely breastfeeding	☐	☐
Mostly breastfeeding with some bottle-feeding	☐	☐
Equally breastfeeding and bottle-feeding	☐	☐
Mostly bottle-feeding and some breastfeeding	☐	☐
Almost entirely bottle-feeding (only tried breastfeeding a few times)	☐	☐
Entirely bottle-feeding (never tried breastfeeding)	☐	☐
Other	☐	☐

If other, please describe: ______________________________

____

If you entirely bottle-fed your twins, please go straight to B10 on page 8

B6. How soon after birth did you start breastfeeding?

1st born Within….. _____ minutes or _____ hours or _____ days

2nd born Within….. _____ minutes or _____ hours or _____ days

B7. How easy was it to establish breastfeeding your twins?

	Very easy	Easy	All right	Difficult	Very difficult
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B8. What was your main method of breastfeeding?

	Mostly fed directly from the breast	Equally fed directly from the breast and gave expressed milk	Mostly gave expressed breast milk
1st born	☐	☐	☐
2nd born	☐	☐	☐

B9. Are you currently breastfeeding your twins? Yes, 1st born ☐ Yes, 2nd born ☐ Neither ☐

If you are no longer breastfeeding, when did you stop?

1st born _______ weeks after birth

2nd born _______ weeks after birth

7

If you entirely breastfed your twins, please go straight to B17 on page 9

B10. How soon after birth did you start bottle-feeding your twins?

1st born	Within….. _____ minutes	or	_____ hours	or	_____ days
2nd born	Within….. _____ minutes	or	_____ hours	or	_____ days

B11. Why did you start bottle-feeding?

	1st born	2nd born
Following advice from health professional	☐	☐
Following advice from friends or family	☐	☐
Breastfeeding was too difficult	☐	☐
Baby did not gain enough weight on breast milk alone	☐	☐
Easier to fit into daily routine	☐	☐
Allows other people to feed my baby	☐	☐

If other, please describe ____

____

B12. Are you currently bottle-feeding your twins?

Yes, 1st born	Yes, 2nd born	Neither
☐	☐	☐

Now we are interested in learning more about <u>how much milk</u> your twins took. Because babies' milk requirements increase as they get older, it is easier to think about how much they took at one specific age. So to answer the questions, please think back to when they were <u>about three months old</u>

If you did not bottle-feed your twins at around 3 months, please go straight to B17 on page 9

B13. What size bottle did you normally use when the twins were <u>about three months old</u>?

	125ml / 4oz	250ml / 9oz	390ml / 12oz	Unsure
1st born	☐	☐	☐	☐
2nd born	☐	☐	☐	☐

8

B14. How full did you normally fill the bottle?

	Completely full	Mostly full	Half full or less	or	How much formula milk per bottle?
1st born	☐	☐	☐		____ ml or ____oz
2nd born	☐	☐	☐		____ ml or ____oz

B15. Most of the time, how much of the bottle did your babies drink?

	All of it	Most of it	Half or less	or	How much formula milk?
1st born	☐	☐	☐		____ ml or ____oz
2nd born	☐	☐	☐		____ ml or ____oz

B16. What size teat did you use when the twins were <u>about three months old</u>?

	Fast flow	Medium flow	Slow flow	Variable teat	Unsure
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

To answer the following questions, please think back to when your twins were <u>about three months old</u>

B17. On average, how many times did you feed your babies during each 24 hour period (one day and one night) when they were <u>about three months old</u>? Please write 0 if you did not breastfeed or bottle-feed your babies when they were about three months old

	Breastfeeding	and / or	Bottle-feeding
1st born	_____ times per day		_____ times per day
2nd born	_____ times per day		_____ times per day

B18. On average, how long did your babies feed for in a typical daytime feed when they were <u>about three months old</u>? Please write 0 if you did not breastfeed or bottle-feed your babies when they were about three months old

	Breastfeeding	and / or	Bottle-feeding
1st born	_____ minutes per feed		_____ minutes per feed
2nd born	_____ minutes per feed		_____ minutes per feed

9

HOW ACTIVE ARE YOUR TWINS

These questions ask about your twins' physical activity in their first three months of life.
For each behaviour, please indicate how often the baby did this

C1.	**During feeding, how often did your babies …**		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	lie or sit quietly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	wave their arms	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C2.	**During sleep, how often did your babies …**		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	toss about in the crib	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	move from the middle to the end of the crib	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	sleep in one position only	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C3.	**When being dressed or undressed, how often did your babies…**		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	wave or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or try to roll away	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

10

C4.	**When put into the bath water,** how often did your babies …		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	splash or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or turn around	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

C5.	**When placed on his/her back,** how often did your babies …		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	wave their arms or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or turn around	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

C6.	**When placed in a seat (e.g. high chair, push chair, car seat), how often did your babies…**		Very rarely	Less than half the time	About half the time	More than half the time	Almost always
	wave their arms or kick	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	squirm or turn their body	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
	sit quietly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

C7. How old were your babies when they first crawled on hands and knees?

1st born	________	months	Not yet	☐
2nd born	________	months	Not yet	☐

C8. How old were your babies when they could sit up without being supported?

1st born	________	months	Not yet	☐
2nd born	________	months	Not yet	☐

11

APPETITE

These questions are about your twins' appetite over their first three months of life.
We are specifically interested in the period when your twins were fed milk only,
i.e. no solid foods or pre-prepared baby food yet

D1. How would you rate your twins' appetites in their first three months?

	Poor	OK	Good	Very Good	Excellent
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

D2. Did either of your twins generally take more milk than the other in their first three months?

1st born took much more milk	1st born took a little more milk	Each took about the same amount	2nd born took a little more milk	2nd born took much more milk
☐	☐	☐	☐	☐

How would you describe your twins' feeding styles at a typical daytime feed in their first three months?

			Never	Rarely	Sometimes	Often	Always
D3.	**My baby sucked vigorously**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D4.	**My baby sucked steadily and rhythmically**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D5.	**My baby seemed contented while feeding**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D6.	**My baby frequently wanted more milk than I provided**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D7.	**My baby loved milk**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

12

These are some more questions about how your twins feed. Again thinking back to the <u>first three months</u>, please choose which box is most appropriate for each of your babies

			Never	Rarely	Sometimes	Often	Always
D8.	My baby had a big appetite	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D9.	My baby finished feeding quickly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D10.	My baby became distressed while feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D11.	My baby got full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D12.	If allowed to, my baby would take too much milk	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D13.	My baby took more than 30 minutes to finish feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D14.	My baby got full before taking all the milk I thought he/she should have had	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D15.	My baby fed slowly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

13

			Never	Rarely	Sometimes	Often	Always
D16.	Even when my baby had just eaten well he/she was happy to feed again if offered	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D17.	My baby found it difficult to manage a complete feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D18.	My baby was always demanding a feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D19.	My baby sucked more and more slowly during the course of a feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D20.	If given the chance, my baby would always be feeding	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D21.	My baby enjoyed feeding time	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D22.	My baby could easily take a feed within 30 minutes of the last one	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

14

HOW YOU FEED YOUR TWINS

The previous section asked some general questions about your feeding.

Now we are interested in learning more about how you fed your twins day-to-day over the <u>first three months.</u> We are particularly interested in whether you changed feeding in different situations

Again, thinking back to the <u>first three months</u>, please choose which box is most appropriate for each of your babies

			Never	Rarely	Sometimes	Often	Always
E1.	**I knew when my baby was hungry**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E2.	**I knew when my baby was full**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E3.	**If my baby cried it was usually because he/she was hungry**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E4.	**I worried if my baby did not feed much on one occasion**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E5.	**If my baby wanted to be fed before the next scheduled feed, I fed him/her earlier than usual**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E6.	**When my baby got fussy I tried feeding to settle him/her down**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E7.	**I worried if my baby fed too much on one occasion**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

15

Still thinking back to the first three months, please choose for each of your babies which box is most appropriate

			Never	Rarely	Sometimes	Often	Always
E8.	I gave my baby a large feed to get him/her to sleep longer	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E9.	I fed my baby to keep him/her quiet when with others	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E10.	I was careful not to feed my baby too frequently	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E11.	I was careful not to feed my baby too large an amount	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
If my baby stopped feeding, I …							
E12.	… tried other methods to encourage him/her e.g. moved baby into a different position or switched breasts	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E13.	… let him/her have a break then try again a bit later	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
If my baby didn't feed much on one occasion, I …							
E14.	… made sure he/she took a larger amount at the next feed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E15.	… offered him/her another feed a bit sooner than I normally would	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

16

Please only answer these questions if you ever bottle-fed either of your twins during the first three months

If you entirely breastfed your twins, please go straight to F1 on page 18

			Never	Rarely	Sometimes	Often	Always
E16.	I tried to make my baby finish everything in the bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E17.	If my baby finished the bottle quickly, I made up another	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E18.	If I worried my baby wasn't eating enough, I added a bit more formula in his/her bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E19.	If I worried my baby was not feeding enough I changed to a more filling formula	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

Please only answer these questions if you fed your twins with a mixture of bottle-feeding and breast-feeding during the first three months

If you entirely bottle-fed your twins, please go straight to F1 on page 18

			Never	Rarely	Sometimes	Often	Always
E20.	If my baby was still hungry after a breast-feed, I fed him/her a bottle	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E21.	I fed my baby by breast, but gave a bottle before bed to help encourage sleep through the night	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

17

SOLID FOODS

The following section is about solid foods
(i.e. anything other than milk, including mashed up foods and ready prepared baby food)

F1. How old were the twins the very first time solid foods of any kind were eaten (i.e. anything other than milk)?

1st born ____ weeks or ____ months Not yet ☐

If neither of your twins has started solid foods, please go straight to F12 on page 21

F2. How easy was it to wean your twins onto solid food?

	Very easy	Easy	OK	Difficult	Very difficult
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

F3. How did you decide to start the twins on solid foods?

	1st born	2nd born
Following advice from health professional	☐	☐
Following advice from friends or family	☐	☐
Milk alone was not enough	☐	☐
Easier to fit into family routine	☐	☐
Baby showed interest in solid foods	☐	☐
Allergy to milk	☐	☐
Other, please describe:	☐	☐

1st born ____

____

2nd born ____

____

18

F4. **In general how much did your baby enjoy starting solid foods?**

	Did not enjoy it at all	Enjoyed it a little	Enjoyed it a lot
1st born	☐	☐	☐
2nd born	☐	☐	☐

F5. **Have your twins started taking solid foods every day?**

	Yes	No	
1st born	☐	☐	If No, please go straight to F8 on this page
2nd born	☐	☐	

F6. **At what age did your twins start taking solid foods every day?**

1st born ________ months old

2nd born ________ months old

F7. **At present, how many times per day does your baby have solid foods?**

1st born ______ times per day

2nd born ______ times per day

F8. **When eating solid food, which of the following statements describes your twins' feeding most accurately?**

	Generally needs to be fully fed by an adult	Generally needs to be fed by an adult but also eats with fingers	Generally eats with spoon but needs help	Generally eats with spoon without help
1st born	☐	☐	☐	☐
2nd born	☐	☐	☐	☐

F9. **When were your twins first given finger foods (i.e. foods babies can pick up and feed to themselves)?**

1st born	Age ________ months	Not yet	☐
2nd born	Age ________ months	Not yet	☐

19

F10.	Has either of your twins tried these foods yet? If so, how old were they when they first tried it?		
		Age when first tried	Not yet tried
Baby rice, cereal, rusks or bread	1st born	______ months	☐
	2nd born	______ months	☐
Vegetables (uncooked, cooked or pureed, fresh, frozen or tinned)	1st born	______ months	☐
	2nd born	______ months	☐
Chips (e.g. oven fries, smiley faces, potato waffles or wedges)	1st born	______ months	☐
	2nd born	______ months	☐
Potatoes or sweet potatoes	1st born	______ months	☐
	2nd born	______ months	☐
Processed meat (e.g. sausages, burger)	1st born	______ months	☐
	2nd born	______ months	☐
Other meat (e.g. chicken, lamb, pork, beef)	1st born	______ months	☐
	2nd born	______ months	☐
Fish (fresh, frozen, tinned or fish fingers)	1st born	______ months	☐
	2nd born	______ months	☐
Eggs	1st born	______ months	☐
	2nd born	______ months	☐
Dairy products (e.g. milk, cheese, yoghurt)	1st born	______ months	☐
	2nd born	______ months	☐
Fizzy drinks with sugar (e.g. 7up, coke)	1st born	______ months	☐
	2nd born	______ months	☐
Low calorie fizzy drinks (e.g. 7up zero, diet coke)	1st born	______ months	☐
	2nd born	______ months	☐

20

F11.	Has either of your twins tried these foods yet? If so, how old were they when they first tried it?		
		Age when first tried	Not yet tried
Squash and/or fruit drinks with sugar (e.g. ribena, robinsons fruit shoot)	1st born	_______ months	☐
	2nd born	_______ months	☐
Low calorie squash and/or fruit drinks (e.g. ribena light, robinsons fruit shoot no added sugar)	1st born	_______ months	☐
	2nd born	_______ months	☐
Pure fruit juice (100% juice)	1st born	_______ months	☐
	2nd born	_______ months	☐
Savoury snacks (e.g. crisps, cheese biscuits)	1st born	_______ months	☐
	2nd born	_______ months	☐
Fruit (uncooked, cooked, pureed, fresh, frozen or tinned)	1st born	_______ months	☐
	2nd born	_______ months	☐
Sweet snacks (e.g. cakes, biscuits, ice cream)	1st born	_______ months	☐
	2nd born	_______ months	☐
Sweets (e.g. chocolate, fruit sweets)	1st born	_______ months	☐
	2nd born	_______ months	☐

F12. Please give the date on which you completed this booklet? ___/___/_____ DD MM YYYY

Thank you

very much for filling in this booklet

PLEASE CHECK that you have given details on <u>YOUR TWINS' GROWTH on page 3</u> or send us copies of the relevant pages from your twins health records (little red book)

21

Space for any additional comments you would like to make

Please return both booklets using the freepost envelope and send it to:

Gemini
Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT

23

Appendix 1.7. Gemini 15 month questionnaire (T1)

Family ID Number □□□□□□□

WELCOME TO

gemini

health and development in twins

15 months booklet

From baby to toddler

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
gemini@public-health.ucl.ac.uk

HOW TO FILL IN THIS BOOKLET

Thank you for taking part in Gemini and agreeing to fill out this booklet.

- We know that there are a lot of questions, but it's important for us to get a full picture of your twins' circumstances.
- Everything you tell us will be kept strictly confidential.
- It may sound obvious, but please write as clearly as possible to help us use all the valuable information you have provided.

Here is an example of how a question *could* be answered.

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

1. **Do you enjoy being part of Gemini?** Yes ☑ No ☐

   Why is this? ...My twins are special and I like helping research...

THIS QUESTIONNAIRE IS TO BE COMPLETED WHEN YOUR TWINS ARE

ABOUT 15 MONTHS OLD

IF THEY ARE OLDER, PLEASE COMPLETE THE QUESTIONNAIRE THINKING BACK TO WHEN THEY WERE ABOUT 15 MONTHS

2

TO START
We are exploring possibilities to use email and online web services for short updates (for example about your twins' growth). Therefore we would like to know how many families participating in Gemini have access to email and online web-services

A1. **Do you have easy access to the internet?** Yes ☐ No ☐

A2. **What is your email address?** ______________________ No email ☐

A3. **Would you be willing to respond to short questionnaires by email or online?** Yes ☐ No ☐

If No, could you tell us why? ______________________

A4. **Please confirm the first names and date of birth of your twins**

Name 1st born ______________ **Name 2nd born** ______________

Date of birth ____ / ____ / 2007
DD MM

A5. **What is your relationship to the twins?**

Mother of the twins ☐ Father of the twins ☐ Other, please describe: ______________________

A6. **How many days per week do your twins go to nursery?**
(please write 0 if they do not go to nursery)

1st born ____ days per week
2nd born ____ days per week

A7. **Do you (or your partner) currently have a job?**

	On maternity leave	Yes, full time	Yes, part-time	No	Stay at home to look after children	Not applicable
You	☐	☐	☐	☐	☐	
Your partner	☐	☐	☐	☐	☐	☐

3

YOUR TWINS' GROWTH

We would like to learn about your twins' growth since we last contacted you (February-April 2008). This information might be in your child's health record (little red book) or you may have kept your own records

B1. Please provide any measurements of your twins' length / height taken since we last contacted you (February-April 2008) and indicate whether the measurement was taken while the twins were lying down or standing up

	1st born				2nd born				How was length/height measured?	
Date measured	cms		feet	inches	cms		feet	inches	Lying down	Standing up
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐

B2. Do you have scales to weigh your twins at home? Yes ☐ No ☐

If Yes, what kind of weighing scale is it? Mechanical (dial display) ☐ Electronic (digital display) ☐ Unsure ☐

B3. Please provide any measurements of your twins' weight taken since we last contacted you (February-April 2008) and indicate whether measurements came from health professional or your own records. Please give current weights by weighing your twins in indoor clothes without shoes. If you do not have any scales, a neighbour or your GP surgery may have some you can use

	1st born				2nd born				These measurement came from...	
Date measured	kgs		lbs	oz	kgs		lbs	oz	Health professional /health record	Own records
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐
___/___/_____ DD MM YYYY	_____	or	_____	_____	_____	or	_____	_____	☐	☐

4

B4. How would you describe your child's weight at the moment?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

B5. How concerned are you about your child's weight at the moment?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

B6. How likely do you think it is that your child will be overweight in 2 years' time?

	Unlikely	Somewhat likely	Very likely
1st born	☐	☐	☐
2nd born	☐	☐	☐

B7. How concerned would you be if your child was overweight in 2 years' time?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

B8. How likely do you think it is that your child will be underweight in 2 years' time?

	Unlikely	Somewhat likely	Very likely
1st born	☐	☐	☐
2nd born	☐	☐	☐

B9. How concerned would you be if your child was underweight in 2 years' time?

	Not concerned	Somewhat concerned	Very concerned
1st born	☐	☐	☐
2nd born	☐	☐	☐

B10. How old were your twins when they could first sit up without being supported?	1st born	______ months	Not yet ☐
	2nd born	______ months	Not yet ☐
B11. How old were your twins when they first crawled on their hands and knees?	1st born	______ months	Not yet ☐
	2nd born	______ months	Not yet ☐
B12. How old were your twins when they could walk a few steps without any support?	1st born	______ months	Not yet ☐
	2nd born	______ months	Not yet ☐
B13. How old were your twins when they said their first word?	1st born	______ months	Not yet ☐
	2nd born	______ months	Not yet ☐

THE TWINS' ILLNESSES AND ACCIDENTS

C1. Has either of the twins seen a doctor due to a serious illness or accident since we last contacted you (February-April 2008)?

Yes, 1st born	Yes, 2nd born	Neither
☐	☐	☐

C2. If Yes, please describe each illness or accident. Use the back of the questionnaire if you need extra space

		Description of illness or accident	Age of twin (months)	Number of doctor visits (GP or specialist)	Number of hospital nights
1st born	1	______	______	______	______
	2	______	______	______	______
	3	______	______	______	______
	4	______	______	______	______
2nd born	1	______	______	______	______
	2	______	______	______	______
	3	______	______	______	______
	4	______	______	______	______

6

APPETITE

These questions are about your twins' appetite at the moment. You may recognise some of the questions from the previous questionnaire about when they were only having milk. Now we are interested about the current situation when they are eating solid foods

D1. How would you rate your twins' appetites at the moment?

	Poor	OK	Good	Very Good	Excellent
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

D2. Does one of your twins generally eat more than the other?

1st born eats much more	1st born eats a little more	Each eat about the same amount	2nd born eats a little more	2nd born eats much more
☐	☐	☐	☐	☐

How would you describe your twins' eating styles on a typical day?

			Never	Rarely	Sometimes	Often	Always
D3.	**My child loves food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D4.	**My child eats more when irritable**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D5.	**My child has a big appetite**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D6.	**My child finishes his/her meal quickly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D7.	**My child is interested in food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D8.	**My child cannot eat a meal if he/she has had a snack just before**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D9.	**My child refuses new foods at first**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D10.	**My child eats slowly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

7

			Never	Rarely	Sometimes	Often	Always
D11.	**My child looks forward to mealtimes**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D12.	**My child wants to eat (e.g. reaches out or asks) when he/she smells certain foods**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D13.	**My child wants to eat (e.g. reaches out or asks) when he/she sees certain foods**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D14.	**My child is always asking for food**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D15.	**My child eats more when grumpy**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D16.	**If allowed to, my child would eat too much**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D17.	**My child eats more when upset**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D18.	**My child enjoys a wide variety of foods**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D19.	**My child leaves food on his/her plate or in the jar at the end of a meal**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D20.	**My child takes more than 30 minutes to finish a meal**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐
D21.	**Given the choice, my child would eat most of the time**	1^{st} born	☐	☐	☐	☐	☐
		2^{nd} born	☐	☐	☐	☐	☐

8

			Never	Rarely	Sometimes	Often	Always
D22.	**My child enjoys tasting new foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D23.	**My child gets full before his/her meal is finished**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D24.	**My child enjoys eating**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D25.	**My child refuses to eat certain types of food (e.g. vegetables, meat)**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D26.	**My child is difficult to please with meals**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D27.	**My child eats more than usual if he/she really enjoys the taste of a food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D28.	**My child decides that he/she does not like a food, even without tasting it**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D29.	**My child eats more and more slowly during the course of a meal**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D30.	**Even when my child has just eaten well, he/she is happy to eat again if offered**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D31.	**My child wants to eat (e.g. reaches out or asks) when he/she sees others eating**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D32.	**My child gets full up easily**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D33.	**My child is interested in tasting food he/she has not tasted before**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
D22.	My child enjoys tasting new foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D23.	My child gets full before his/her meal is finished	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D24.	My child enjoys eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D25.	My child refuses to eat certain types of food (e.g. vegetables, meat)	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D26.	My child is difficult to please with meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D27.	My child eats more than usual if he/she really enjoys the taste of a food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D28.	My child decides that he/she does not like a food, even without tasting it	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D29.	My child eats more and more slowly during the course of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D30.	Even when my child has just eaten well, he/she is happy to eat again if offered	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D31.	My child wants to eat (e.g. reaches out or asks) when he/she sees others eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D32.	My child gets full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D33.	My child is interested in tasting food he/she has not tasted before	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

9

E6. Compared to other children of the same age and sex, how physically active is your child?

	Much less active	Somewhat less active	About average	Somewhat more active	Much more active
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

E7. How many hours would you estimate your child watches TV or DVDs during the following times on a typical weekday (Monday through Friday) at this time of year?

	Morning (6 am to 12 noon)	Afternoon (12 noon to 6 pm)	Evening (6 pm to midnight)
1st born	_____ hours per day	_____ hours per day	_____ hours per day
2nd born	_____ hours per day	_____ hours per day	_____ hours per day

E8. How many hours would you estimate your child watches TV or DVDs during the following times on a weekend day (Saturday or Sunday) at this time of year?

	Morning (6 am to 12 noon)	Afternoon (12 noon to 6 pm)	Evening (6 pm to midnight)
1st born	_____ hours per day	_____ hours per day	_____ hours per day
2nd born	_____ hours per day	_____ hours per day	_____ hours per day

E9. When does your child usually go to bed in the evening?

1st born _____ : _____ (please write hour : minutes e.g. 6:15 pm or 18:15)

2nd born _____ : _____

E10. When does your child usually wake up in the morning?

1st born _____ : _____ (please write hour : minutes e.g. 6:15 am)

2nd born _____ : _____

E11. How long does you child usually sleep during the daytime?

1st born _____ hours per day

2nd born _____ hours per day

E12. Do either of your twins usually wake up at night? Yes 1st born ☐ Yes 2nd born ☐ Neither ☐

If Yes, how often does your child wake up at night?

1st born	_____ times per night	_____ times per week
2nd born	_____ times per night	_____ times per week

If Yes, for how long does your child wake up at night?

1st born	_____ hours	or	_____ minutes per night
2nd born	_____ hours	or	_____ minutes per night

11

E6. Compared to other children of the same age and sex, how physically active is your child?

	Much less active	Somewhat less active	About average	Somewhat more active	Much more active
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

E7. How many hours would you estimate your child watches TV or DVDs during the following times on a typical weekday (Monday through Friday) at this time of year?

	Morning (6 am to 12 noon)	Afternoon (12 noon to 6 pm)	Evening (6 pm to midnight)
1st born	_____ hours per day	_____ hours per day	_____ hours per day
2nd born	_____ hours per day	_____ hours per day	_____ hours per day

E8. How many hours would you estimate your child watches TV or DVDs during the following times on a weekend day (Saturday or Sunday) at this time of year?

	Morning (6 am to 12 noon)	Afternoon (12 noon to 6 pm)	Evening (6 pm to midnight)
1st born	_____ hours per day	_____ hours per day	_____ hours per day
2nd born	_____ hours per day	_____ hours per day	_____ hours per day

E9. When does your child usually go to bed in the evening?

1st born _____ : _____ (please write hour : minutes e.g. 6:15 pm or 18:15)

2nd born _____ : _____

E10. When does your child usually wake up in the morning?

1st born _____ : _____ (please write hour : minutes e.g. 6:15 am)

2nd born _____ : _____

E11. How long does you child usually sleep during the daytime?

1st born _____ hours per day

2nd born _____ hours per day

E12. Do either of your twins usually wake up at night? Yes 1st born ☐ Yes 2nd born ☐ Neither ☐

If Yes, how often does your child wake up at night?

1st born _____ times per night _____ times per week

2nd born _____ times per night _____ times per week

If Yes, for how long does your child wake up at night?

1st born _____ hours or _____ minutes per night

2nd born _____ hours or _____ minutes per night

HOW YOU FEED YOUR TWINS

The following questions are about how you feed your twins day-to-day.
If the described behaviour does not apply to you as you never do this, please tick "never"

			Never	Rarely	Sometimes	Often	Always
F1.	**I allow my child to choose which foods to have for meals**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F2.	**I give my child something to eat to make him/her feel better when he/she is feeling upset**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F3.	**I keep track of the high fat foods that my child eats**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F4.	**I ask other people not to feed my child unhealthy foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F5.	**I encourage my child to eat a wide variety of foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F6.	**I decide how many snacks my child should have**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F7.	**I use foods that my child likes as a way to get him/her to eat "healthy" foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F8.	**If my child misbehaves I withhold his/her favourite food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F9.	**I praise my child if he/she eats fruit or vegetables**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F10.	**I give my child something to eat to make him/her feel better when he/she has been hurt**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F11.	**I let my child decide when he/she would like to have his/her meal**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F12.	**I encourage my child to eat fruit or vegetables**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

12

			Never	Rarely	Sometimes	Often	Always
F13.	**I use puddings as a bribe to get my child to eat his/her main course**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F14.	**I present fruit or vegetables in an attractive way to my child**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F15.	**I give my child something to eat to make him/her feel better when he/she is grumpy**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F16.	**I try not to eat unhealthy foods when my child is around**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F17.	**I keep track of the sugary foods that my child eats**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F18.	**I reward my child with something to eat when he/she is well-behaved**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F19.	**I let my child eat between meals whenever he/she wants**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F20.	**I give my child something to eat to make him/her feel better when he/she is feeling irritable**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F21.	**I decide what my child eats between meals**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F22.	**I avoid buying unhealthy foods and bringing them into the house**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F23.	**I keep track of the foods my child's been eating when he/she is not with me (e.g. with a childminder or family member)**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F24.	**I praise my child if he/she eats a new food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

13

Here are a few more questions about how you feed your twins day-to-day. Remember, if the described behaviour does not apply to you as you never do this, please tick "never"

			Never	Rarely	Sometimes	Often	Always
F25.	I avoid going to cafes or restaurants with my child that sell unhealthy foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F26.	I give my child something to eat to occupy him/her (e.g. when in company or travelling)	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F27.	My child should always eat all of the food I give him/her	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F28.	I show my child how much I enjoy eating healthy foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F29.	I have to be especially careful to make sure my child eats enough	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F30.	I model healthy eating for my child by eating healthy foods myself	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F31.	If I did not guide or regulate my child's eating, he/she would eat much less than he/she should	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F32.	I try to eat healthy foods in front of my child, even if they are not my favourite	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F33.	I insist my child eats some fruit or vegetables, even if he/she doesn't want them	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F34.	I try to show enthusiasm about eating healthy foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F35.	If my child thinks he/she isn't hungry, I try to get him/her to eat anyway	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

14

			Not at all 1	2	3	4	5	6	Strictly 7
F36.	I limit my child's access to sugary foods	1st born	☐	☐	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐	☐	☐
F37.	I limit my child's access to high fat foods	1st born	☐	☐	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐	☐	☐
F38.	I limit the portion sizes of sugary foods that I give to my child	1st born	☐	☐	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐	☐	☐
F39.	I limit the portion sizes of high fat foods that I give to my child	1st born	☐	☐	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐	☐	☐

F40. If you limit your child's access to some foods, what is the most important reason?

	I do not limit access to food	For physical health	For dental health	For weight control	Other, please describe
1st born	☐	☐	☐	☐	☐ ____________
2nd born	☐	☐	☐	☐	☐ ____________

SOLID FOODS

You may recognise this section from the previous questionnaire. We are repeating it because many babies hadn't tried any solid foods or had only tried some of the foods. We apologise for the duplication, but would like to get a full picture of the foods your twins have tried up to now

		1st born	2nd born
G1.	**At what age did your twins start taking solid foods every day?**	____ months	____ months
G2.	**When were your twins first given finger foods (i.e. foods children can pick up and feed to themselves)?**	____ months	____ months

G3. How easy was it to wean your twins onto solid food?

	Very easy	Easy	OK	Difficult	Very difficult
1st born	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐

G4. In general how much did your twins enjoy starting solid foods?

	Did not enjoy it at all	Enjoyed it a little	Enjoyed it a lot
1st born	☐	☐	☐
2nd born	☐	☐	☐

G5. When eating solid food, which of the following statements describes your twins?

	Generally needs to be fully fed by an adult	Generally needs to be fed by an adult but also eats with fingers	Generally eats with spoon but needs help	Generally eats with spoon without help
1st born	☐	☐	☐	☐
2nd born	☐	☐	☐	☐

15

As many children had not tried most of the foods listed, we are repeating this section. Please complete the following question to tell us which foods your twins have tried up to now

G6. How old were your twins when they first tried the following foods?

	1st born		2nd born	
	Age when first tried	Never tried	Age when first tried	Never tried
Baby rice, cereal, rusks or bread	____ months	☐	____ months	☐
Vegetables (uncooked, cooked or pureed, fresh, frozen or tinned)	____ months	☐	____ months	☐
Chips (e.g. oven fries, smiley faces, potato waffles or wedges)	____ months	☐	____ months	☐
Potatoes or sweet potatoes	____ months	☐	____ months	☐
Processed meat (e.g. sausages, burger)	____ months	☐	____ months	☐
Other meat (e.g. chicken, lamb, pork, beef)	____ months	☐	____ months	☐
Fish (fresh, frozen, tinned or fish fingers)	____ months	☐	____ months	☐
Eggs	____ months	☐	____ months	☐
Dairy products (e.g. milk, cheese, yoghurt)	____ months	☐	____ months	☐
Fizzy drinks with sugar (e.g. 7up, coke)	____ months	☐	____ months	☐
Low calorie fizzy drinks (e.g. 7up zero, diet coke)	____ months	☐	____ months	☐
Squash or fruit drinks with sugar (e.g. ribena, robinsons fruit shoot)	____ months	☐	____ months	☐
Low calorie squash or fruit drinks (e.g. ribena light, robinsons fruit shoot no added sugar)	____ months	☐	____ months	☐
Pure fruit juice (100% juice)	____ months	☐	____ months	☐
Savoury snacks (e.g. crisps, cheese biscuits)	____ months	☐	____ months	☐
Fruit (uncooked, cooked, pureed, fresh, frozen or tinned)	____ months	☐	____ months	☐
Sweet snacks (e.g. cakes, biscuits, ice cream)	____ months	☐	____ months	☐
Sweets (e.g. chocolate, fruit sweets)	____ months	☐	____ months	☐

G7. How much do your twins like the following foods at the moment?		Has never tried	Dislikes a lot	Dislikes	Likes	Likes a lot
Baby rice, cereal, rusks or bread	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Vegetables (uncooked, cooked or pureed, fresh, frozen or tinned)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Chips (e.g. oven fries, smiley faces, potato waffles or wedges)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Potatoes or sweet potatoes	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Processed meat (e.g. sausages, burger)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Other meat (e.g. chicken, lamb, pork, beef)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Fish (fresh, frozen, tinned or fish fingers)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Eggs	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Dairy products (e.g. milk, cheese, yoghurt)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Fizzy drinks with sugar (e.g. 7up, coke)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
Low calorie fizzy drinks (e.g. 7up zero, diet coke)	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

17

How much do your twins like the following foods at the moment?		Has never tried	Dislikes a lot	Dislikes	Likes	Likes a lot
Squash or fruit drinks with sugar (e.g. ribena, robinsons fruit shoot)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Low calorie squash or fruit drinks (e.g. ribena light, robinsons fruit shoot no added sugar)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Pure fruit juice (100% juice)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Savoury snacks (e.g. crisps, cheese biscuits)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Fruit (uncooked, cooked, pureed, fresh, frozen or tinned)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Sweet snacks (e.g. cakes, biscuits, ice cream)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐
Sweets (e.g. chocolate, fruit sweets)	1^{st} born	☐	☐	☐	☐	☐
	2^{nd} born	☐	☐	☐	☐	☐

G8. **Please give the date on which you completed this booklet** ___/___/_____
DD MM YYYY

Thank you

very much for filling in this booklet

18

Space for any additional comments you would like to make

Please return this booklet to:

Gemini
Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
FREEPOST SE64 15

Appendix 1.8. Gemini food likes and dislikes Questionnaire (T5)

Family ID Number ☐☐☐☐☐☐☐

WELCOME TO

gemini

health and development in twins

Food Likes and Dislikes

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
1-19 Torrington Place
London, WC1E 6BT
gemini@public-health.ucl.ac.uk

TO START

A1. Please confirm the first names and date of birth of your twins

Name 1st born ____________________ **Name 2nd born** ____________________

Date of birth ____ / _____ / 2007
DD MM

A2. What is your relationship to the twins?

Mother of the twins	Father of the twins	Other, please describe:
☐	☐	______________________________

A3. Are there any restrictions on what your twins eat?

Yes, 1st born	Yes, 2nd born	Neither
☐	☐	☐

If yes please specify (tick all that apply):

Religious	1st born	☐	(please give details) ____________________
	2nd born	☐	(please give details) ____________________
Health	1st born	☐	(please give details) ____________________
	2nd born	☐	(please give details) ____________________
Vegetarian	1st born	☐	(please give details) ____________________
	2nd born	☐	(please give details) ____________________
Other	1st born	☐	(please give details) ____________________
	2nd born	☐	(please give details) ____________________

2

YOUR TWINS' GROWTH

We would like to update the information on your twins' growth since we last contacted you.

B1. If you have any measurements of your twins' height or weight taken since we last contacted you please enter them here.

If you haven't measured your twins recently please use the height chart and instructions we have sent to add today's heights and the scales we sent you to add today's weights.

- When measuring the twins' heights make sure they aren't wearing shoes.
- Where possible please give weights in kilograms (kg) and weigh your twins in indoor clothes without shoes.

Date measured		Height				Weight			
		cms		feet	inches	kgs		stones	lbs
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____

3

YOUR TWINS' FOOD PREFERENCES

The following questions are about how much your twins like and dislike different foods.
We realise that it is a long list; this is because we need to know about lots of different foods.
If your child has never eaten a food, please tick 'Has never tried'.

C1. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Beef	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Beefburger, hamburger	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Lamb	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pork	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Chicken	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Chicken nuggets	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Turkey	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Bacon	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Ham	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sausages	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

4

C2. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Liver	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pâté	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Fish fried in batter or breadcrumbs *e.g. fish fingers*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Plain white fish *e.g. cod, haddock, snapper*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Oily fish *e.g. mackerel, salmon*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Tinned tuna	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Seafood, shellfish *e.g. prawns*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Baked beans	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pulses *e.g. lentils, chickpeas*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Nuts *e.g. peanuts*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Eggs: boiled, poached	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

5

C3. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Eggs: scrambled	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Eggs: fried	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pizza	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
White bread	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Brown bread	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Savoury snacks, cheese biscuits *e.g. Chedders, Tuc*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cheese (processed) *e.g. Dairylea, Kraft, cheese strings*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cheese (hard) *e.g. cheddar*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cottage cheese	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cheese (cream) *e.g. Philadelphia*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cheese (soft) *e.g. Brie, Camembert*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

6

C4. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Porridge or Ready Brek	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Frosted or high sugar cereal *e.g. Ricicles, Frosties, Coco Pops*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Other cereals (non high-sugar) *e.g. Weetabix, Cornflakes, Bran Flakes*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Potatoes: boiled, mashed or jacket	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Potatoes: chips	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Potatoes: roast, fried	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Broccoli	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cabbage, spring greens	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cauliflower	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Green beans	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

7

C5. How much do your twins like the following foods at the moment?		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Runner beans	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Leeks	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Mushrooms	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Onions	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Parsnips	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Peas	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Salad greens *e.g. lettuce*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sweet potatoes	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sweetcorn	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Butternut squash, pumpkin	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sprouts	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

8

C6. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Swede	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cucumber	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Beetroot	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Aubergine	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Okra	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Mange tout	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sugarsnap peas	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Celery	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Spinach	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Yams	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Plantain	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

C7. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Carrots (raw)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Carrots (cooked)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Peppers, red/green (raw)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Peppers, red/green (cooked)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Tomatoes (fresh)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Tomatoes (tinned, as pasta sauce)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Avocado	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Apples (raw)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Apples (baked or pureed)	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Bananas	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Oranges	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

10

C8. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Tangerines, satsumas, clementines	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Grapes	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Melon	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Peaches, nectarines	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pears	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Plums	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Apricots	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Strawberries	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Raspberries	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Dried fruit *e.g. raisins*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Blueberries	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

C9. **How much do your twins like the following foods at the moment?**

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Figs	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pineapple	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Mango	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pomegranate	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Papaya	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Kiwi fruit	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cherries	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Grapefruit	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Milk	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Butter	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Margarine	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

12

C10. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Cream	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sweet biscuits (plain) *e.g. rich tea, digestives*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Chocolate biscuits	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Buns, pastries *e.g. scones, Danish pastries*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Cakes	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Ice cream	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Ice lollies	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Custard	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Dairy desserts *e.g. mousse*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Yoghurt, fromage frais *e.g. Muller, Petits Filous*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Crisps	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

C11. How much do your twins like the following foods at the moment?

		Has never tried	Dislikes a lot	Dislikes	Neither likes nor dislikes	Likes	Likes a lot
Jam	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Chocolate	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Sweets *e.g. Fruit pastilles, Starburst*	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Tomato ketchup	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Mayonnaise	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Rice	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐
Pasta	1st born	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐

C12. Would you say that in general your twins like and dislike the same foods? Yes ☐ No ☐

C13. If No, why do you think it is that your twins have different food preferences? Please continue on the back page of the questionnaire if you need extra space.

____

____

____

14

HOW YOUR TWINS FEEL ABOUT FOOD

These questions are about how your twins eat and their attitudes to food at the moment. You may recognise some of the questions from earlier questionnaires. Now your twins are older and have a broader diet we are interested about the current situation.

How would you describe your twins' eating styles on a typical day?

			Never	Rarely	Sometimes	Often	Always
D1.	**My child refuses new foods at first**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D2.	**My child enjoys a wide variety of foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D3.	**My child enjoys tasting new foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D4.	**My child refuses to eat certain types of food (e.g. vegetables, meat)**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D5.	**My child is difficult to please with meals**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D6.	**My child decides that he/she does not like a food, even without tasting it**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
D7.	**My child is interested in tasting food he/she has not tasted before**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

		Yes	No
D8.	**In general do your twins react in the same way to new foods that they haven't tasted before?**	☐	☐

D9. **If No, why do you think it is that your twins react to new foods differently?** Please continue on the back page of the questionnaire if you need extra space.

____

____

15

When thinking about your twins' eating, to what extent do you agree with the following statements?

			Strongly disagree	Disagree	Agree	Strongly agree
E1.	**My child has a sweet tooth**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E2.	**My child likes very salty foods**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E3.	**My child likes to eat the same foods time and again**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E4.	**My child strongly dislikes many foods**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E5.	**My child is a picky eater**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E6.	**My child likes foods cooked in a certain way (e.g. mashed potatoes but not boiled)**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E7.	**My child likes only a few foods**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E8.	**My child plays with the food on his/her plate instead of eating it**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E9.	**My child likes food presented in a certain way (e.g. no foods touching each other on the plate)**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐

When thinking about your twins' eating, to what extent do you agree with the following statements?

			Strongly disagree	Disagree	Agree	Strongly agree
E10.	**My child prefers drinks to food**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E11.	**My child is not interested in food**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E12.	**My child is easy to feed**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E13.	**If my child doesn't know what is in a food, he/she won't try it**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E14.	**My child dislikes foods with pips or 'bits'**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E15.	**My child is constantly sampling new and different foods**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E16.	**My child doesn't trust new foods**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E17.	**My child dislikes foods with certain textures (e.g. soft, lumpy, chewy)**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐
E18.	**My child is afraid to eat things he/she has never had before**	1st born	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐

17

HOW YOUR TWINS RESPOND TO DIFFERENT SITUATIONS

This final section is about how your twins respond to things other than food.

How does your child respond to the situations listed below on a typical day?

			Never	Rarely	Sometimes	Often	Always
F1.	**My child shows distress during face washing/hair brushing etc.**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F2.	**My child reacts negatively when touched by a person**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F3.	**My child avoids textures or won't play with messy materials**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F4.	**My child dislikes being tickled**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F5.	**My child dislikes being cuddled or being held**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F6.	**My child has trouble adjusting to water temperature or dislikes water**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F7.	**My child reacts negatively to unexpected or loud sounds**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F8.	**My child is disturbed by too much light or brightness**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

18

WHAT'S COMING UP NEXT FOR GEMINI?

The Gemini study has lots of exciting things coming up and you can help by completing the section below. For more details about the 'Tiny Tastes' study and the 'Home Environment' interviews please see the letter accompanying this booklet.

G1. If you would be interested in taking part in the Gemini 'Tiny Tastes' study aimed at encouraging your twins to eat more vegetables please let us know by ticking the Yes box below

Yes, my family and I would like to take part in 'Tiny Tastes' ☐	**No**, we are not interested in taking part in 'Tiny Tastes' ☐	If No, Please give reason: ______________________________ ______________________________

G2. Our next questionnaire will be about the 'Home Environment'. We are hoping to complete this part of Gemini through telephone interviews so we can hear from you directly! Therefore we would really appreciate it if you could provide a contact telephone number below

Home telephone _________________ and / or Mobile telephone _________________

G3. Please give the date on which you completed this booklet ___/____/_____ DD MM YYYY

Thank you

very much for filling in this booklet

19

Space for any additional comments you would like to make

Please return this booklet to:

Gemini
Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
1-19 Torrington Place
London, WC1E 6BT
FREEPOST SE64 15

20

Appendix 2. Additional materials from studies 1, 2, 3 and 4

Appendix 2.1. Table summarising the literature on factors associated with food acceptance (preference or intake) in children

Author & year	Sample Characteristics				Outcome Variable: intake or preference	Associated variables	Measure	Design	Findings
	n	**Age**	**Sex**	**Nationality / Ethnicity**					
Cooke et l., 2004	564	2-6 years	B=267 G=287	UK	Intake	Sex, age, ethnicity, maternal education, parental F&V intake, breast-feeding and early introduction to F&V, children's neophobia and enjoyment of food.	Parent completed qstnr.	CS –pre-school based	Higher maternal education, older age and female gender were related to V intake. Parental intake, breast-feeding and early introduction to F&V were related to intake of F&V. Neophobia and enjoyment of food were related to F&V intake.
Cooke & Wardle, 2005	1232	4-16 years	B=604 G=628	UK	Preference	Sex and age	Self-report qstnr (age 8-18). Joint parent and child completed qstnr (age 4-7).	CS- school based	Number of foods liked decreased with age as a function of number of foods tried. Fatty/sugary foods were liked most, followed by fruit, starches, meat, eggs, fish, dairy foods and lastly veg. Liking for F&V was higher for girls than boys. Liking for fatty & sugary foods, meat, processed meat products and eggs was higher for boys.
Fisher & Birch, 1995	18	3-5 years	B=8 G=10	USA	Intake and preference (fat only)	anthropometrics	Intake measured using 30-hour weighed food intake. Self-reported ranked preference	CS	Children indicating strong preferences for high-fat foods had higher total fat intakes. Children's fat preferences were related to their triceps skinfold measurement. Children with the strongest preferences for high-fat foods and the highest total fat intakes had heavier parents.
Hill, Wardle et al. 2009	366	7-9 years	NR	UK	Preference	Sex, anthropometrics	Self-report qstnr		Vs were liked less than fatty or sugary foods or Fs, but no difference between liking for Fs and for fatty or sugary foods. Boys had a higher liking for fatty or sugary foods than girls. There was no association between liking for any of the food

Author & year	Sample Characteristics				Outcome Variable: intake or preference	Associated variables	Measure	Design	Findings
	n	Age	Sex	Nationality / Ethnicity					
									categories and adiposity.
Howard et al., 2012	245	2 years	B=202 G=118	Australia	Preference	maternal food preferences, child neophobia and repeated exposure to new foods,	Parent completed qstnr	CS – control arm of intervention study	Maternal F&V and non-core food liking related to children's liking and inversely related to number of F&V never tried. Child neophobia negatively related to number of F&V liked, but not to non-core food liking. Repeated exposures to new foods (≥6) were not related to F&V or non-core liking. Earlier intro of solids related to non-core food preference. Earlier breastfeeding cessation related to number of non-core foods liked and tried.
Jones et al., 2010	7285	7 years	B=3699 G=3586	UK	Intake	Sex, maternal F&V intake, household rules, 'child's eating characteristics', maternal education, household income,	three 1day food diaries	CS – cohort study	Girls ate more F&V than boys. Maternal F&V intake was predictive of child F&V intake. Higher maternal education and greater household expenditure on food was related to higher F&V intake. Parental rules to serve fruit and/or vegetables every day were associated with higher F&V intake, but child choosiness was associated with lower intake.
Lakkakula, Zanovec, et al. 2008	341	7-8 years	B=147 G=194	USA (clack only)	Preference	anthropometrics	Self-report qstnr	CS- school based	Negative association between children's mean F&V preference score and BMI for age percentile. Children with very low preference for F&V were 5.5 times more likely to be at risk of overweight or overweight, than children who reported a high preference for F&V.
Lanfer et al, 2012	1696	6-9 year olds	48.7% B	Europe: multiple	Preference (fat and sweet)	Sex, age, parental education and parental BMI, anthropometrics	Preference: Taste test Intake: parental-reported	CS: multi-site	Overweight including obesity was positively associated with fat preference and sweet preference. Results from adjusted models with BMI z-score as dependent variable were similar but results only significant for

Author & year	Sample Characteristics				Outcome Variable: intake or preference	Associated variables	Measure	Design	Findings
	n	Age	Sex	Nationality / Ethnicity					
							questionnaires.		fat preference in girls.
Lien et al., 2001	885	14-21 years	B=490 G=395	Norway	Intake	age	Self-report qstnr.	LT –cohort study	Consumption of F&V decreased between ages 14 and 21, while sugar-containing soft drinks increased. Tracking of consumption patterns into young adulthood was seen for all foods indicating some stability of eating behaviour into young adulthood.
Lytle et al., 2000	294	8-14 years		USA	Intake	Sex and age	24-hour dietary recalls	CS – school based	F consumption fell by 41% between the third and the eighth grades while V consumption fell by 25%. No relationship between sex and F or V intake
McGowan et al., 2012	434	2-5 years	B=202 G=232	UK	Intake	Parent intake, parent feeding style, home availability, TV viewing	Parent completed qstnr	CS- pre-school based	Maternal intake was associated with both core and non-core food intake. Encouragement (PFSQ) was associated with core food intake. Higher monitoring was associated with lower intake of non-core snacks and higher intake of F&V. Home availability was associated with intake of non-core snacks but not core foods. TV viewing related to intake of non-core snacks and drinks.
Möller et al, 2012	3624	5 years	B=202 G=232	Netherlands	Intake	Breastfeeding, age at solid introduction.	Parent completed qstnr (FFQ)	Prospective birth cohort	Children who received solids before 4 months had a higher F intake than children who received solids at 6 months but no associations were found with V intake. Longer exclusive breast-feeding was associated with higher V intake at age 5 but no associations were found for F.
Perez-Rodrigo et al., 2003	3534	2-24 years	B=1629 G=1905	Spanish	Intake and preference	Sex and age	Joint parent and child completed qstnr.	CS - population survey	Pasta, rice and meat were the favourite foods and vegetables, legumes and fish least liked regardless of age. More boys

Author & year	Sample Characteristics				Outcome Variable: intake or preference	Associated variables	Measure	Design	Findings
	n	**Age**	**Sex**	**Nationality / Ethnicity**					
									reported a dislike for fish compared to girls but there were no other sex differences.
Pearson et al., 2007	n/a	6-18 years	n/a	various	Intake	Sex, age, SES, parental intake, modelling, home availability, multiple additional family-related and personal factors	various	Systematic review	Parental modelling and intake, home availability, family rules and parental encouragement were positively related to children's F&V consumption. In adolescents, positive associations were found between parental occupation and fruit intake and between parental education and F&V intake.
Rasmussen et al., 2006	n/a	6-18 years	n/a	various	Intake	Sex, age, SES, parental intake, home availability, multiple additional family-related and personal factors	various	Systematic review	The determinants best supported by evidence are: age (younger), gender (girls), socio-economic position (higher), preferences, parental intake (higher), and home availability/accessibility (higher) are all consistently positively associated with intake.
Reynolds et al., 1999	3758 (total)	8-16 years	B=1805 G=1953	USA: Alabama, Georgia, Louisiana, Minnesota.	Intake	sex and ethnicity	24-hour recalls and seven-day food records (Georgia only)	CS – school-based	Girls consuming more servings of Vs than boys but only at one site (Georgia). In Georgia, African-Americans consumed more servings of F&V combined. In Georgia and Minnesota, African-Americans consumed more servings of F than European-Americans. In Minnesota, European-Americans consumed more Vs.
Ricketts, 1997	88	9-12	B= 51 G= 37	USA	preference (fat only)	anthropometrics	3 day diet records. Self-reported preference ratings	CS- school based	Children who preferred high fat snack items had high dietary fat intakes. Tricep skinfold measurement and BMI correlated positively with high fat food preferences

Author & year	Sample Characteristics				Outcome Variable: intake or preference	Associated variables	Measure	Design	Findings
	n	Age	Sex	Nationality / Ethnicity					
Russell & Worsley , 2007	371	2-5 years	B=191 G=164	Australia	Preference	Socio-demographics: SES, parental education, breastfeeding, nursery attendance, age and sex	Parent completed qstnr.	CS – convenience sample survey	Sociodemographic variables explained little of the variation in food preferences. 4-year-olds liked more foods than 2-year-olds, but no significant age differences in mean liking for food groups. Girls scored slightly higher on V preference than boys but this only approached significance.
Skinner et al., 2002	70	2-8 years	NR	USA	Preference	Sex, age, maternal preference, neophobia	Parent completed qstnr.	LT–cohort study	Most liked foods =breads, desserts, snack foods, and meats. Most disliked foods were veg. Few changes in food preferences over time. Mothers' and children's FP were moderately correlated. Children were less likely to have tried foods their mothers disliked. Children's neophobia was related to numbers of foods tried and number of foods liked.
Skinner et al., 2003	70	6-8 years	NR	USA	Intake (variety)	Breastfeeding, early F&V variety and exposure, maternal preference.	3 days of dietary data	LT	Variety scores did not differ significantly from 6 to 8 years old. Mothers' V preferences predicted children's V variety. Children's F variety was predicted by either early food variety or exposure and breast-feeding duration.
Wardle, Guthrie et al, 2001	428	4-5 years	B=205 G=223	UK	Preference, intake	Parental BMI	Taste test: Intake of palatable foods under conditions of satiety.	CS –twin population subsample	Children from obese/overweight families had higher preference for fatty foods in a taste test and a lower liking for Vs.
Wardle, Sanderson et al., 2001	428	4-5 years	B=205 G=223	UK	Preference	Sex	Parent completed qstnr.	CS – twin population subsample	V preference was marginally higher for girls than for boys (p=0.05), but no sex differences in liking for desserts, meat and fish or Fruit.

Abbreviations: B; boys, G; girls, NR; not reported, CS; cross-sectional, LT; longitudinal, V; vegetable, F; fruit

Appendix 2.2. Food preferences and within pair intraclass correlations by zygosity, for individual foods at T5 (Study 3)

Food Items	**% children who tried food** N (%)	**Mean liking score**[1] Mean (SD)	**MZ**[2] **Intraclass correlation** (95% CI)	**DZ**[2] **Intraclass correlation** (95% CI)
Vegetables				
Salad leaves	2482 (92.4)	-0.73 (1.16)	0.86 (0.84-0.88)	0.63 (0.60-0.66)
Sprouts	2112 (78.6)	-0.29 (1.20)	0.83 (0.81-0.85)	0.67 (0.64-0.70)
Cabbage	2417 (90.0)	0.06 (1.13)	0.90 (0.89-0.92)	0.67 (0.65-0.70)
Raw peppers	2277 (84.8)	0.07 (1.24)	0.85 (0.83-0.87)	0.71 (0.69-0.74)
Cooked peppers	2445 (91.0)	0.14 (1.06)	0.94 (0.93-0.95)	0.81 (0.80-0.83)
Onions	2580 (96.1)	0.17 (0.92)	0.89 (0.88-0.90)	0.73 (0.73-0.75)
Parsnips	2303 (85.8)	0.20 (1.04)	0.89 (0.88-0.91)	0.73 (0.71-0.75)
Cauliflower	2584 (96.3)	0.24 (1.12)	0.87 (0.86-0.89)	0.67 (0.65-0.70)
Green beans	2541 (94.7)	0.41 (1.16)	0.85 (0.83-0.87)	0.64 (0.61-0.67)
Sweet potatoes	2272 (84.5)	0.52 (0.93)	0.90 (0.89-0.92)	0.82 (0.80-0.84)
Broccoli	2660 (99.1)	0.78 (1.19)	0.76 (0.73-0.79)	0.47 (0.43-0.50)
Raw carrots	2588 (96.4)	0.86 (1.13)	0.86 (0.84-0.88)	0.59 (0.56-0.62)
Sweet corn	2627 (97.8)	1.00 (1.05)	0.76 (0.73-0.79)	0.58 (0.55-0.61)
Peas	2667 (99.3)	1.02 (1.02)	0.65 (0.61-0.69)	0.52 (0.48-0.55)
Potatoes	2679 (99.7)	1.03 (1.00)	0.81 (0.79-0.83)	0.55 (0.51-0.58)
Cooked carrots	2674 (99.6)	1.17 (0.97)	0.78 (0.75-0.81)	0.51 (0.47-0.54)
Other vegetables[3]				
Mushrooms	2432 (90.5)	-0.16 (1.14)	0.81 (0.78-0.83)	0.57 (0.54-0.61)
Tinned tomatoes	2643 (98.4)	1.14 (0.87)	0.90 (0.88-0.91)	0.70 (0.68-0.73)
Cucumber	2607 (97.1)	0.78 (1.27)	0.72 (0.66-0.75)	0.56 (0.53-0.59)
Fruits				
Fresh tomatoes	2618 (97.4)	0.19 (1.38)	0.71 (0.68-0.74)	0.44 (0.41-0.48)
Kiwi	2164 (80.6)	0.39 (1.20)	0.84 (0.81-0.86)	0.58 (0.55-0.62)
Raw apples	2666 (99.3)	0.53 (0.75)	0.73 (0.70-0.76)	0.37 (0.33-0.41)
Pineapple	2410 (89.4)	0.57 (1.15)	0.85 (0.82-0.86)	0.67 (0.65-0.70)
Mango	2083 (77.6)	0.60 (1.08)	0.92 (0.91-0.93)	0.75 (0.72-0.77)
Plums	2318 (86.3)	0.68 (1.10)	0.88 (0.87-0.90)	0.73 (0.71-0.75)
Melon	2522 (93.9)	0.80 (1.16)	0.86 (0.84-0.87)	0.71 (0.68-0.73)
Peaches	2421 (90.2)	0.84 (1.07)	0.90 (0.89-0.91)	0.68 (0.65-0.70)
Blueberries	2218 (82.6)	0.92 (1.20)	0.78 (0.75-0.80)	0.56 (0.52-0.59)
Raspberries	2452 (91.3)	0.93 (1.18)	0.81 (0.79-0.84)	0.63 (0.59-0.65)
Pears	2590 (96.5)	1.03 (1.00)	0.85 (0.83-0.87)	0.52 (0.48-0.55)
Oranges	2613 (97.3)	1.05 (1.10)	0.77 (0.74-0.80)	0.44 (0.40-0.48)
Tangerines	2606 (97.0)	1.15 (1.09)	0.73 (0.70-0.76)	0.40 (0.36-0.44)
Strawberries	2663 (99.1)	1.43 (0.99)	0.67 (0.63-0.70)	0.43 (0.39-0.47)
Grapes	2660 (99.0)	1.58 (0.84)	0.69 (0.65-0.72)	0.38 (0.34-0.42)
Other fuits[3]				
Bananas	2670 (99.4)	1.47 (0.87)	0.59 (0.54-0.63)	0.36 (0.32-0.40)
Baked apples	2394 (89.1)	0.91 (0.99)	0.95 (0.94-0.95)	0.82 (0.81-0.84)
Protein				
Beef burger	2064 (76.8)	0.45 (1.02)	0.86 (0.84-0.88)	0.63 (0.60-0.66)
Pork	2220 (82.3)	0.62 (0.90)	0.88 (0.86-0.89)	0.68 (0.65-0.71)
Lamb	2136 (79.5)	0.64 (0.94)	0.88 (0.86-0.89)	0.70 (0.68-0.73)
Beef	2493 (92.8)	0.74 (0.95)	0.81 (0.79-0.84)	0.58 (0.55-0.61)
Bacon	2221 (82.7)	0.85 (1.05)	0.81 (0.78-0.83)	0.54 (0.50-0.57)
Turkey	2292 (85.3)	0.87 (0.80)	0.81 (0.78-0.83)	0.76 (0.73-0.78)
White fish	2402 (89.6)	0.88 (0.91)	0.88 (0.87-0.90)	0.71 (0.68-0.73)

Ham	2540 (94.5)	1.15 (1.01)	0.75 (0.71-0.77)	0.35 (0.31-0.39)
Chicken	2608 (97.1)	1.31 (0.82)	0.72 (0.69-0.75)	0.60 (0.57-0.63)
***Other protein items*[3]**				
Sausages	2571 (95.7)	1.45 (0.83)	0.76 (0.74-0.79)	0.54 (0.50-0.57)
Chicken nuggets	2148 (80.0)	1.00 (0.98)	0.86 (0.84-0.88)	0.75 (0.72-0.77)
Tuna	2267 (84.4)	0.61 (1.09)	0.83 (0.80-0.85)	0.71 (0.68-0.73)
Battered fish	2603 (96.9)	1.27 (0.85)	0.83 (0.81-0.85)	0.60 (0.57-0.63)
Dairy				
Mayonnaise	2035 (75.8)	0.32 (1.12)	0.82 (0.80-0.85)	0.60 (0.57-0.63)
Scrambled eggs	2497 (92.9)	0.45 (1.26)	0.82 (0.80-0.84)	0.62 (0.59-0.65)
Cream	2208 (82.2)	0.54 (1.00)	0.85 (0.83-0.92)	0.57 (0.53-0.60)
Processed cheese	2242 (83.4)	0.60 (1.24)	0.80 (0.77-0.82)	0.68 (0.65-0.71)
Cream cheese	2061 (76.7)	0.61 (1.04)	0.89 (0.87-0.91)	0.74 (0.72-0.77)
Eggs	2544 (94.7)	0.63 (1.27)	0.77 (0.74-0.79)	0.59 (0.56-0.62)
Margarine	2160 (80.4)	0.91 (0.90)	0.86 (0.84-0.87)	0.77 (0.75-0.79)
Custard	2521 (93.9)	0.94 (1.07)	0.90 (0.89-0.91)	0.73 (0.70-0.75)
Butter	2546 (99.3)	1.21 (0.85)	0.80 (0.78-0.82)	0.67 (0.64-0.70)
Hard cheese	2646 (98.5)	1.26 (0.99)	0.64 (0.60-0.68)	0.39 (0.35-0.43)
***Other dairy items*[3]**				
Yoghurt	2667 (99.3)	1.74 (0.60)	0.72 (0.69-0.75)	0.42 (0.38-0.46)
Snacks				
Sweet buns	2524 (94.0)	1.00 (0.94)	0.82 (0.91-0.93)	0.77 (0.74-0.78)
White bread	2635 (98.1)	1.18 (0.70)	0.88 (0.87-0.90)	0.85 (0.84-0.87)
Chips	2669 (99.4)	1.23 (0.81)	0.81 (0.79-0.83)	0.60 (0.57-0.63)
Cakes	2674 (99.6)	1.38 (0.78)	0.82 (0.80-0.84)	0.60 (0.57-0.63)
Plain biscuits	2670 (99.4)	1.50 (0.61)	0.92 (0.91-0.93)	0.70 (0.67-0.72)
Ice cream	2660 (99.0)	1.51 (0.83)	0.74 (0.71-0.77)	0.47 (0.43-0.50)
Crisps	2651 (98.7)	1.61 (0.62)	0.81 (0.78-0.83)	0.63 (0.60-0.66)
Chocolate biscuits	2652 (98.8)	1.64 (0.65)	0.65 (0.62-0.69)	0.61 (0.58-0.64)
Chocolate	2669 (99.4)	1.70 (0.78)	0.63 (0.59-0.67)	0.46 (0.42-0.49)
***Other Snack items*[3]**				
Dessert mousse	2389 (88.9)	1.05 (1.02)	0.91 (0.90-0.92)	0.78 (0.76-0.80)
Sweets	2182 (81.2)	1.19 (1.00)	0.86 (0.84-0.88)	0.64 (0.61-0.67)
Savory snacks	2540 (94.6)	1.27 (0.79)	0.88 (0.86-0.89)	0.72 (0.70-0.75)
Ice lollies	2585 (96.2)	1.42 (0.88)	0.91 (0.90-0.92)	0.73 (0.70-0.75)
***Other foods*[3]**				
Oatmeal	2487 (92.6)	0.75 (1.19)	0.78 (0.76-0.81)	0.65 (0.62-0.67)
Rice	2668 (99.3)	0.97 (0.94)	0.86 (0.85-0.88)	0.70 (0.68-0.72)
Brown bread	2636 (98.1)	1.15 (0.71)	0.91 (0.90-0.92)	0.83 (0.81-0.84)
Cereals (non-sugared)	2659 (99.0)	1.40 (0.73)	0.81 (0.78-0.83)	0.63 (0.60-0.66)
Pasta	2681 (99.8)	1.53 (0.72)	0.83 (0.81-0.85)	0.50 (0.47-0.54)
Roast potatoes	2618 (97.5)	0.92 (0.96)	0.89 (0.88-0.90)	0.73 (0.71-0.75)
Fruit preserves	2628 (97.8)	0.95 (1.05)	0.67 (0.63-0.71)	0.42 (0.38-0.46)
Pizza	2640 (98.3)	1.01 (0.97)	0.72 (0.69-0.75)	0.57 (0.53-0.60)
Baked beans	2641 (98.3)	1.02 (1.12)	0.61 (0.57-0.65)	0.51 (0.48-0.55)
Ketchup	2591 (96.5)	1.24 (1.00)	0.62 (0.58-0.66)	0.41 (0.36-0.47)
Raisins	2653 (99.8)	1.43 (0.90)	0.73 (0.70-0.76)	0.52 (0.49-0.55)

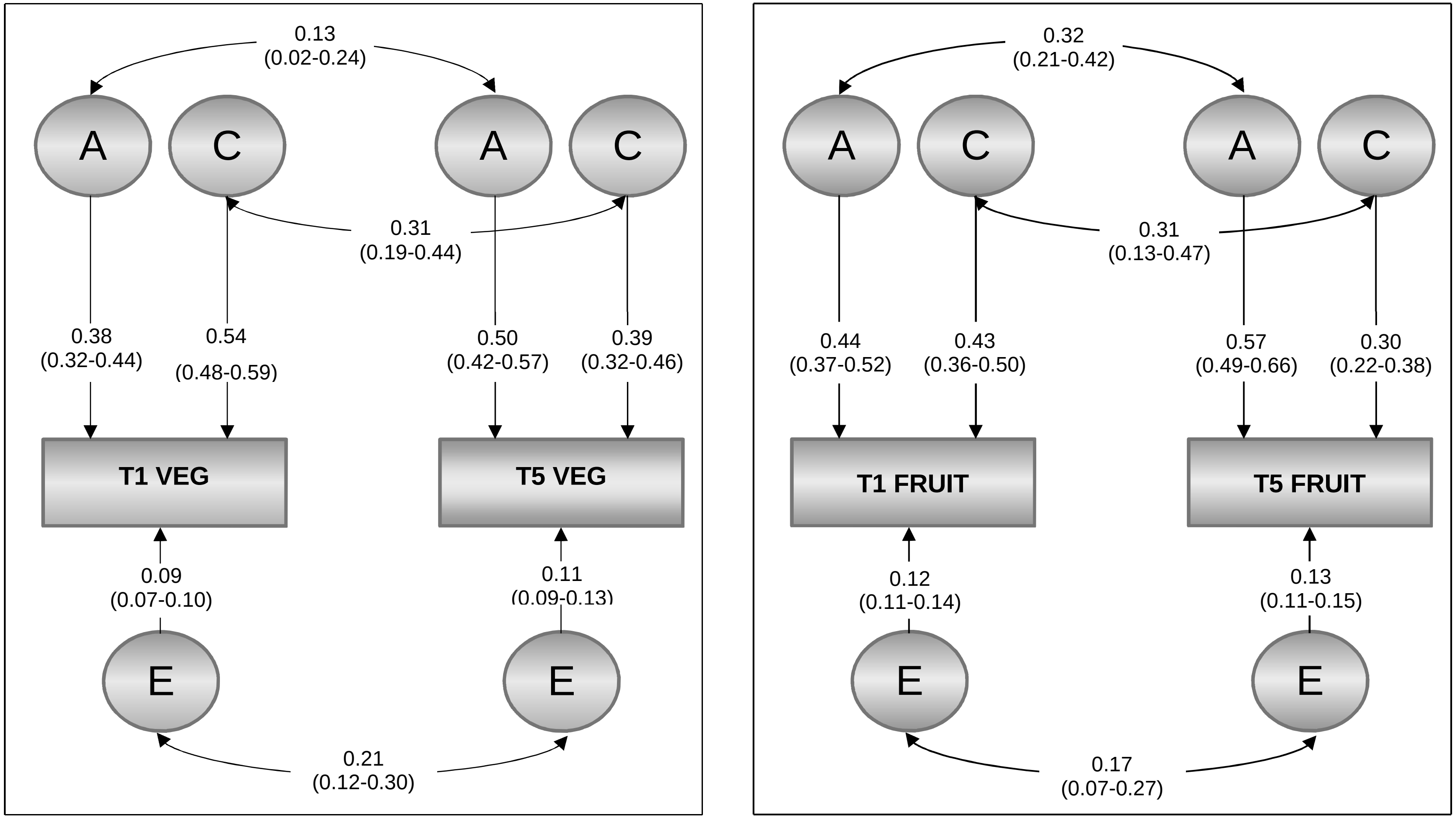
[1] Higher scores indicate higher liking

[2] MZ, monozygotic; DZ, dizygotic.

[3] Items had been tried by 75% of children sampled, but failed to load onto a factor in the PCA

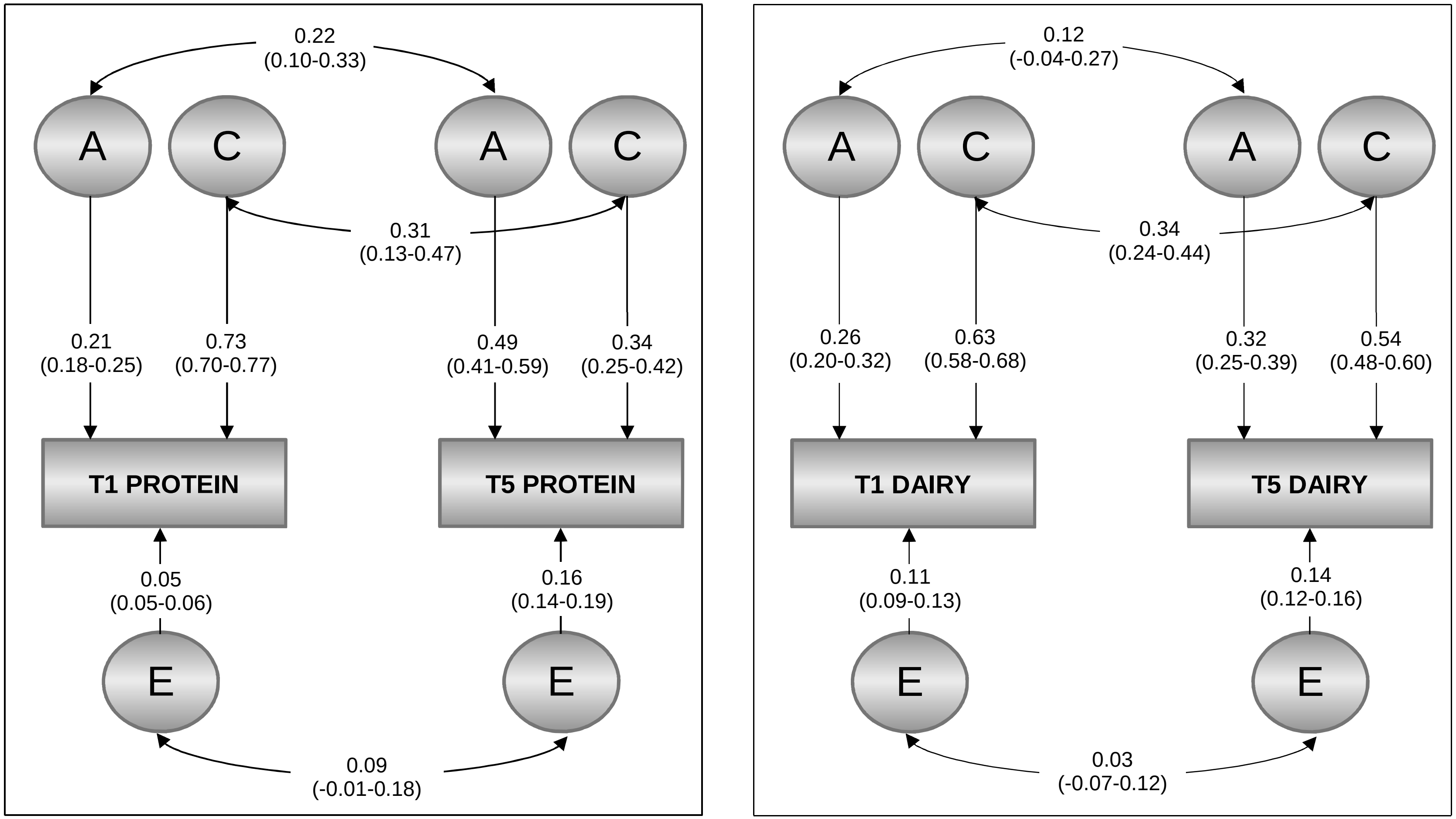
Appendix 2.3. Longitudinal correlated factors models (Study 3)

Longitudinal correlated factors models of genetic and environmental influences on vegetable and fruit preference between T1 & T5



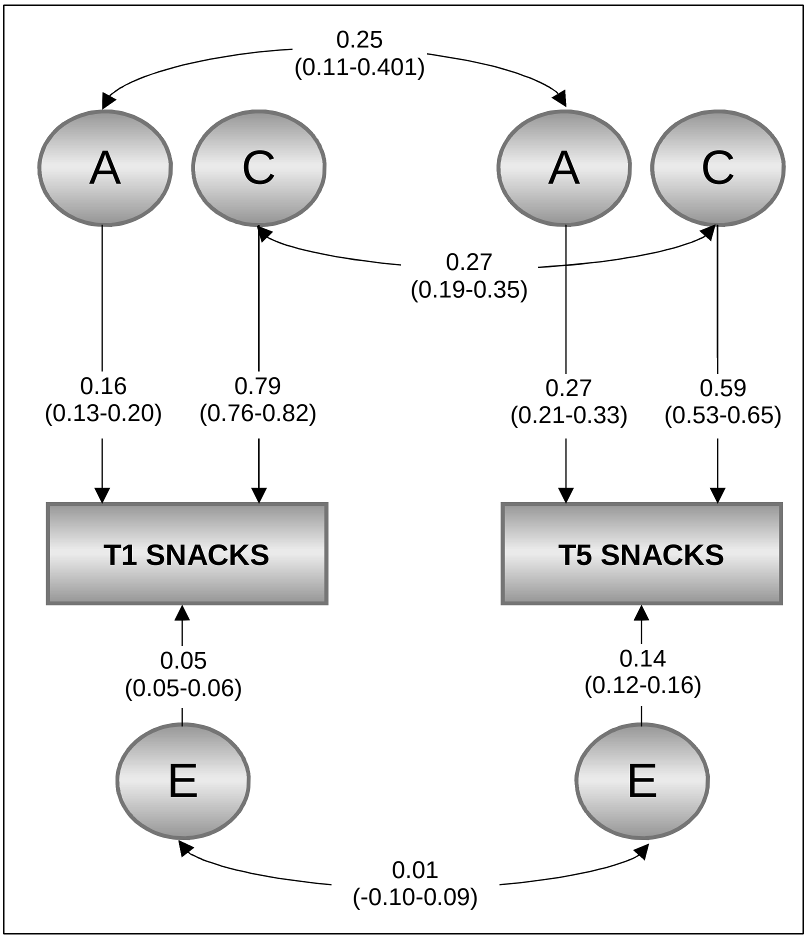
Path diagrams showing genetic and environmental influences on vegetable and fruit preference separately at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. The straight single-headed arrows show the causal paths, and the squared path coefficients on each causal path indicate the total variance in preference, at T1 and T5, explained by A, C and E. The curved double-headed arrows show the genetic, shared environment and unique environment correlations between the trait at T1 and T5.

Longitudinal correlated factors models of genetic and environmental influences on vegetable and fruit preference between T1 & T5



Path diagrams showing genetic and environmental influences on protein and dairy preference at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. The straight single-headed arrows show the causal paths, and the squared path coefficients on each causal path indicate the total variance in preference, at T1 and T5, explained by A, C and E. The curved double-headed arrows show the genetic, shared environment and unique environment correlations between the trait at T1 and T5.

Longitudinal correlated factors models of genetic and environmental influences on snack preference between T1 & T5



Path diagrams showing genetic and environmental influences on snack preference at T1 (15 months) and T5 (3.5 years) for one twin. Circles indicate latent influences which include; additive genetic effects (A), shared environment effects (C), and unique environment effects/error (E).Rectangular boxes represent the measured trait at each age. The straight single-headed arrows show the causal paths, and the squared path coefficients on each causal path indicate the total variance in preference, at T1 and T5, explained by A, C and E. The curved double-headed arrows show the genetic, shared environment and unique environment correlations between the trait at T1 and T5.

Appendix 3. 'Tiny Tastes' study materials

Appendix 3.1. 'Tiny Tastes' participant information sheet – intervention condition

gemini
health and development in twins
www.geministudy.co.uk

tiny tastes

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

<Mothers_Firstname> <Mothers_Surname>
«ADDRESS_1»
«ADDRESS_2»
«ADDRESS_3»
«ADDRESS_4»
«Postcode»

09 May 2013

Dear <Mothers_Firstname>

Family ID Number: GEM<UCL_ID>

Please keep a copy of this information sheet.
Thank you for returning the 'Food Likes and Dislikes' questionnaire and letting us know that you and your family are interested in taking part in the Tiny Tastes study. Tiny Tastes is about encouraging your child to try new foods by making it fun.

Please start by choosing a vegetable that you and your twins will use for the Tiny Tastes game. This will be the same vegetable that you will also use in three short tests. Please pick a vegetable that both twins are not very keen on. The options are: carrots, celery, red pepper, sugar snap peas, cucumber or cabbage. We know from other parents that these are all good choices to try Tiny Tastes with and, because they can be eaten raw, you won't need to do any extra cooking. If your twins like all of these, choose a different vegetable that both twins are not very keen on and that can be eaten raw.

Everyone taking part in the Gemini Tiny Tastes study will be asked to do three short tests with each of their twins to see how much they like the chosen vegetable. The three tests should be completed about 15 days apart and each test needs to be completed with each twin separately. Please read the test instructions to find out how to do the tests and record your results on the attached test record sheets. After you have done all three tests with both twins, please return the completed test record sheets to us in the freepost envelope provided. We have included a Gemini Tiny Tastes Study Plan to help you remember when to complete your tests.

After you have completed Test 2 it will be time to open the envelope containing the Tiny Taste information booklet and pack which explains how to play the Tiny Tastes game. When you open the pack, please read the Tiny Tastes booklet carefully and follow the instructions. You can keep a record of your twins' progress on the Tiny Tastes charts. If possible, we would like you to play Tiny Tastes with each twin separately. We understand that this may be difficult but it will prevent them copying one another.

If you have any questions about Tiny Tastes or you are confused about any of the instructions please call Alison Fildes 0207 6791263 or email the Gemini team:
Gemini@public-health.ucl.ac.uk

Good Luck!

The Gemini Team

Appendix 3.2. ‘Tiny Tastes’ participant information sheet - control condition

gemini
health and development in twins
www.geministudy.co.uk

tiny tastes

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC
HEALTH BEHAVIOUR RESEARCH CENTRE

UCL

<Mothers_Firstname> <Mothers_Surname>
«ADDRESS_1»
«ADDRESS_2»
«ADDRESS_3»
«ADDRESS_4»
«Postcode»

09 May 2013

Dear <Mothers_Firstname>

Family ID Number: GEM<UCL_ID>

Please keep a copy of this information sheet.
Thank you for returning the 'Food Likes and Dislikes' questionnaire and letting us know that you and your family are interested in taking part in the Tiny Tastes study. Tiny Tastes is about encouraging your child to try new foods by making it fun.

Please start by choosing a vegetable that you and your twins will use for the Tiny Tastes game. This will be the same vegetable that you will also use in three short tests. Please pick a vegetable that both twins are not very keen on. The options are: carrots, celery, red pepper, sugar snap peas, cucumber or cabbage. We know from other parents that these are all good choices to try Tiny Tastes with and, because they can be eaten raw, you won't need to do any extra cooking. If your twins like all of these, choose a different vegetable that both twins are not very keen on and that can be eaten raw.

Everyone taking part in the Gemini Tiny Tastes study will be asked to do three short tests with each of their twins to see how much they like the chosen vegetable. The three tests should be completed about 15 days apart and each test needs to be completed with each twin separately. Please read the test instructions to find out how to do the tests and record your results on the attached test record sheets. After you have done all three tests with both twins, please return the completed test record sheets to us in the freepost envelope provided. We have included a Gemini Tiny Tastes Study Plan to help you remember when to complete your tests.

Once we have received your completed Test sheets we will send you the Tiny Taste information booklet and pack which explains how to play the Tiny Tastes game. When you open the pack, please read the Tiny Tastes booklet carefully and follow the instructions. You can keep a record of your twins' progress on the Tiny Tastes charts.

If you have any questions about Tiny Tastes or you are confused about any of the instructions please call Alison Fildes 0207 6791263 or email the Gemini team:
Gemini@public-health.ucl.ac.uk

Good Luck!

The Gemini Team

Appendix 2.3. 'Tiny Tastes' test instructions and record sheets; intervention condition

tiny tastes

gemini
health and development in twins

TEST INSTRUCTIONS

Please complete the tests with each twin separately if you can. We would like you to complete Test 1 and then wait 15 days before completing Test 2. You will start Tiny Tastes the day after you have completed Test 2 and play Tiny Tastes for 14 days, then it will be time for Test 3. To help you remember when to do everything we have included a 'Gemini Tiny Tastes Study Plan'. If you write down the date when you complete Test 1 and record the date every day for 30 days, the plan will remind you when to do the tests and play Tiny Tastes. Please don't worry if you forget for a few days, we would still like you to complete the tests as soon as you remember.

1. First choose the vegetable you will use for the tests. Pick a vegetable that both twins are not keen on. If possible choose from: carrots, celery, red pepper, sugar snap peas, cucumber or cabbage. If your twins like all these vegetables, choose another one that both twins are not keen on and that can be eaten raw.
   (Remember you will be using the same vegetable in all the tests and for Tiny Tastes)

2. Try to carry out the tests at least 1 ½ hours before or after your twins eat. This is so the children are not already full before you begin.
   (If possible the twins should not be in the same room at the same time while doing the tests).

3. Start by cutting up six, small, approximately equal sized pieces of the chosen vegetable (about the size of a 5 pence piece) and put them into your child's bowl/plate. Record the number of pieces on the taste test record sheet.

4. Offer the bowl/plate to your child and invite them to eat as many as they like. Ask them to let you know when they are finished.

5. If the child finishes all the pieces you have given them, cut some more equal sized pieces of the vegetable and continue to offer them until your child has eaten as much as s/he wants. *(Make sure you record any extra pieces you offer on the test record sheet.)*

6. Do not press your child to eat any more than s/he want to and if s/he refuses to eat any at all then that is OK; just record it on the sheet. It is up to your child to decide how much or how little of the vegetable to eat.

7. Once your child has finished, record the number of pieces left and the total amount eaten on the record sheet.

8. Finally record how much you think your child liked the vegetable by ticking one of the boxes on the test record sheet.

9. Repeat steps 2-8 with the other twin.

10. Once you have completed Tiny Tastes and have carried out all three tests with both twins, please send back this booklet in the Freepost envelopes provided (along with the Tiny Taste charts you filled in for each child when playing the Tiny Tastes game)

A short video demonstration of how to carry out the tests is available online at:
www.geministudy.co.uk/tastetest

Family ID Number ☐☐☐☐☐☐☐

tiny tastes gemini health and development in twins

Test 1 record sheet

Start by choosing the vegetable you will use in the tests. This needs to be the same vegetable for both twins. Try and choose a vegetable that both twins are not very keen on. The options we suggest are; carrots, celery, red pepper, sugar snap peas, cucumber or cabbage.

Our chosen vegetable is: ___________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

tiny tastes

gemini
health and development in twins

Test 2 record sheet

Test 2 should take place around 15 days after test 1 (but don't worry too much if you forget, or you are unable to do the tests exactly 15 days apart, we would still like you to carry on with the study as soon as you can). Check on your 'Gemini Tiny tastes Study Plan' to make sure it is time for test 2. Remember, you need to use the same vegetable as you used for the first taste test.

Our chosen vegetable is: ___________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

tiny tastes gemini health and development in twins

Test 3 record sheet

Test 3 should to take place the day after you have finished playing 14 days of Tiny Tastes (but don't worry too much if you forget, or you were unable to play Tiny Tastes every day, we would still like you to carry on with the study as soon as you can). Check on your 'Gemini Tiny tastes Study Plan' to make sure it is time for test 3. Remember, you need to keep using the same vegetable as you used for the other taste tests.

Our chosen vegetable is: ____________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

Once you have completed all 3 tests with both twins and filled in these record sheets, please send them back to the Gemini team using the freepost envelope provided. Remember to include the Tiny Tastes charts for each twin as well.

Appendix 2.3. 'Tiny Tastes' test instructions and record sheets; control condition

tiny tastes

gemini
health and development in twins

TEST INSTRUCTIONS

Please complete the tests with each of your twins separately. You should carry out 3 tests with each twin, 15 days apart. To help you remember when to do the tests we have included a 'Gemini Tiny Tastes Study Plan'. If you write down the date when you complete Test 1 and record the date on the plan every day for 30 days, the study plan will remind you when to carry out test 2 and test 3. Please don't worry if you forget for a few days, we would still like you to complete the tests as soon as you remember.

1. First choose the vegetable you will use for the tests. Pick a vegetable that both twins are not keen on. If possible choose from: carrots, celery, red pepper, sugar snap peas, cucumber or cabbage. If your twins like all these vegetables, choose another one that both twins are not keen on and that can be eaten raw.
   (Remember you will be using the same vegetable in all the tests and for Tiny Tastes)

2. Try to carry out the tests at least 1 ½ hours before or after your twins eat. This is so the children are not already full before you begin.
   (If possible the twins should not be in the same room at the same time while doing the tests).

3. Start by cutting up six, small, approximately equal sized pieces of the chosen vegetable (about the size of a 5 pence piece) and put them into your child's bowl/plate. Record the number of pieces on the taste test record sheet.

4. Offer the bowl/plate to your child and invite them to eat as many as they like. Ask them to let you know when they are finished.

5. If the child finishes all the pieces you have given them, cut some more equal sized pieces of the vegetable and continue to offer them until your child has eaten as much as s/he wants.
   (Make sure you record any extra pieces you offer on the test record sheet.)

6. Do not press your child to eat any more than s/he want to and if s/he refuses to eat any at all then that is OK; just record it on the sheet. It is up to your child to decide how much or how little of the vegetable to eat.

7. Once your child has finished, record the number of pieces left and the total amount eaten on the record sheet.

8. Finally record how much you think your child liked the vegetable by ticking one of the boxes on the test record sheet.

9. Repeat steps 2-8 with the other twin.

10. Once you have completed all 3 tests with both twins please send back the three test record sheets in the Freepost envelope provided.

A short video demonstration of how to carry out the tests is available online at:
www.geministudy.co.uk/tastestest

Family ID Number ☐☐☐☐☐☐☐

tiny tastes

gemini
health and development in twins

Test 1 record sheet

Start by choosing the vegetable you will use in the tests. This needs to be the same vegetable for both twins. Try and choose a vegetable that both twins are not very keen on. The options we suggest are; carrots, celery, red pepper, sugar snap peas, cucumber or cabbage.

Our chosen vegetable is: ____________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

tiny tastes

gemini
health and development in twins

Test 2 record sheet

Test 2 should take place around 15 days after test 1 (but don't worry too much if you forget, or you are unable to do the tests exactly 15 days apart, we would still like you to carry on with the study as soon as you can). Check on your 'Gemini Tiny tastes Study Plan' to make sure it is time for test 2. Remember, you need to use the same vegetable as you used for the first test.

Our chosen vegetable is: ___________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

tiny tastes gemini health and development in twins

Test 3 record sheet

Test 3 should to take place around 15 days after test 2 (but don't worry too much if you forget, or you are unable to do the tests exactly 15 days apart, we would still like you to carry on with the study as soon as you can). Check on your 'Gemini Tiny tastes Study Plan' to make sure it is time for test 3. Remember, you need to keep using the same vegetable as you used for the other tests.

Our chosen vegetable is: ____________________

	Date	Twin's name	Number of vegetable pieces offered	Number of vegetable pieces left	Total number of vegetable pieces eaten by my child
Twin 1					
Twin 2					

Please rate how much you think each twin likes the taste test vegetable by ticking one of the boxes below:

	1 Dislikes a lot	2	3 Dislikes	4	5 Neither Likes nor dislikes	6	7 Likes	8	9 Likes a lot
Twin 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Twin 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

Once you have completed all 3 tests with both twins and filled in these record sheets, please send them back to the Gemini team using the freepost envelope provided.

Appendix 3.4. 'Tiny Tastes' study plan; intervention condition

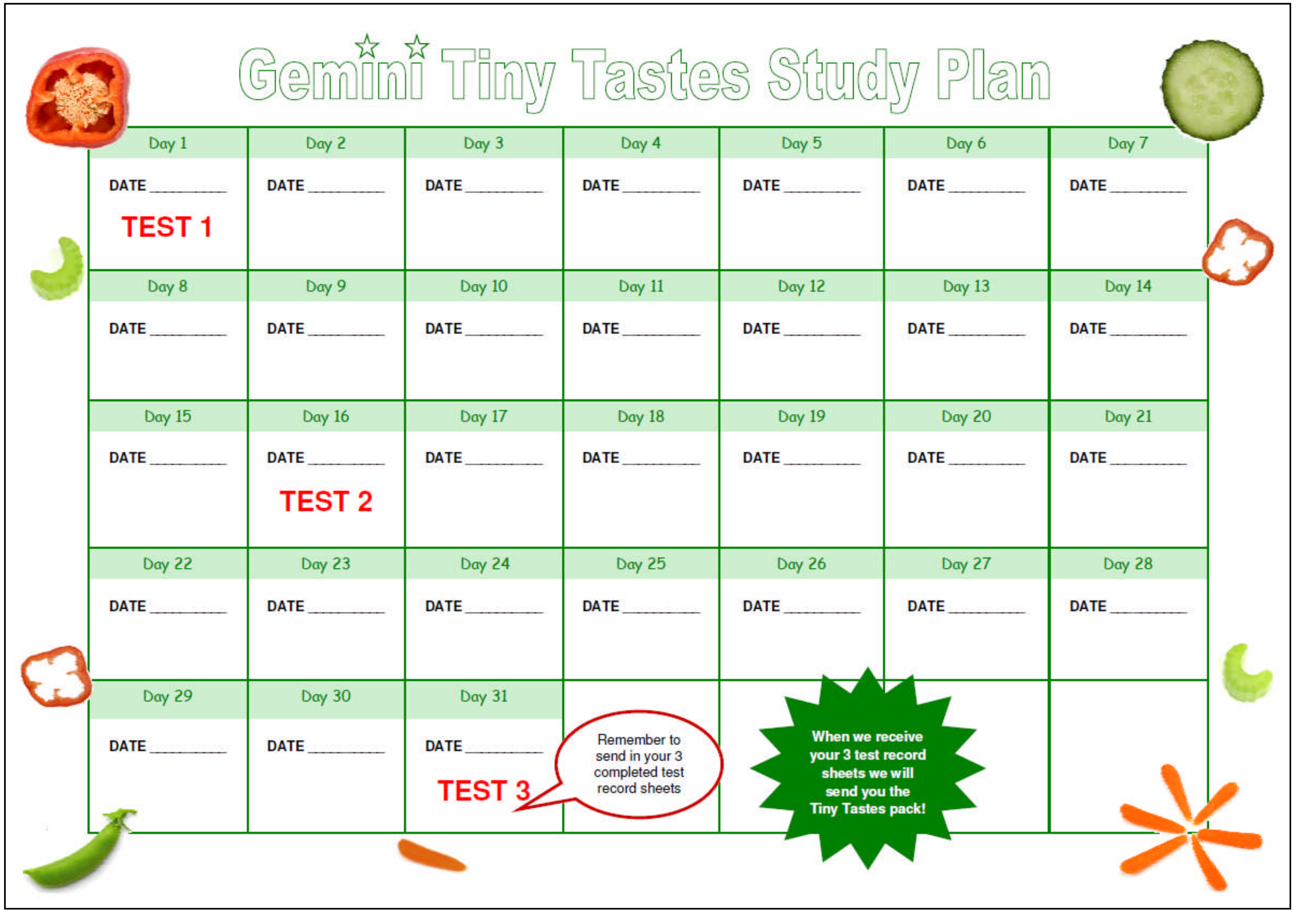
Gemini Tiny Tastes Study Plan

Day 1 DATE ________ TEST 1	Day 2 DATE ________	Day 3 DATE ________	Day 4 DATE ________	Day 5 DATE ________	Day 6 DATE ________	Day 7 DATE ________
Day 8 DATE ________	Day 9 DATE ________	Day 10 DATE ________	Day 11 DATE ________	Day 12 DATE ________	Day 13 DATE ________	Day 14 DATE ________
Day 15 DATE ________	Day 16 DATE ________ TEST 2	Day 17 DATE ________ Tiny Taste 1	Day 18 DATE ________ Tiny Taste 2	Day 19 DATE ________ Tiny Taste 3	Day 20 DATE ________ Tiny Taste 4	Day 21 DATE ________ Tiny Taste 5
Day 22 DATE ________ Tiny Taste 6	Day 23 DATE ________ Tiny Taste 7	Day 24 DATE ________ Tiny Taste 8	Day 25 DATE ________ Tiny Taste 9	Day 26 DATE ________ Tiny Taste 10	Day 27 DATE ________ Tiny Taste 11	Day 28 DATE ________ Tiny Taste 12
Day 29 DATE ________ Tiny Taste 13	Day 30 DATE ________ Tiny Taste 14	Day 31 DATE ________ TEST 3				

Open the envelope and begin Tiny Tastes!

Remember to send in your 3 completed test record sheets and your Tiny Tastes charts for each twin.

Appendix 3.5. 'Tiny Tastes' study plan; control condition



Gemini Tiny Tastes Study Plan

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
DATE ________ TEST 1	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________
Day 8	**Day 9**	**Day 10**	**Day 11**	**Day 12**	**Day 13**	**Day 14**
DATE ________	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________
Day 15	**Day 16**	**Day 17**	**Day 18**	**Day 19**	**Day 20**	**Day 21**
DATE ________	DATE ________ TEST 2	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________
Day 22	**Day 23**	**Day 24**	**Day 25**	**Day 26**	**Day 27**	**Day 28**
DATE ________	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________	DATE ________
Day 29	**Day 30**	**Day 31**				
DATE ________	DATE ________	DATE ________ TEST 3	Remember to send in your 3 completed test record sheets	When we receive your 3 test record sheets we will send you the Tiny Tastes pack!		

Appendix 3.6. ‘Tiny Tastes’ intervention instructions

gemini
health and development in twins
www.geministudy.co.uk

tiny tastes

DEPARTMENT OF EPIDEMIOLOGY & PUBLIC HEALTH BEHAVIOUR RESEARCH CENTRE
UCL

Dear Gemini Family,

Thank you for taking part in the Gemini Tiny Tastes study. Please find enclosed your Tiny Tastes pack which includes; a Tiny Tastes booklet, record charts and stickers. Tiny Tastes is about encouraging your child to try new foods by making it fun. Our research has shown that after tasting a new vegetable between 10 and 14 times, even the most reluctant children like it more and will eat much more of it.

Before you begin...
The 'Gemini Tiny Tastes Study Plan' will let you know when it is time to start Tiny Tastes. The day before starting Tiny Tastes, you should have completed Test 2. If you have not yet completed two tests, please read the test instructions and complete Test 1 and Test 2 - 15 days apart, once you have done this you can start the Tiny Taste game on the day following Test 2.

Tiny Tastes Game
You are now ready to start playing the Tiny Tastes game with your twins, using the same 'special' vegetable that you chose for the tests. The game involves offering this same vegetable to each twin every day for 14 days. Don't worry if you forget to play tiny tastes one day, just skip that Tiny Taste and continue the day after. It is important that you complete the tests as close to 15 days apart as possible. This means that even if you have not managed to do all 14 Tiny Tastes we would still like you to continue with Test 3 approximately 15 days after Test 2. Please read the Tiny Tastes booklet carefully and follow the instructions to start playing.

You will find a pad of Tiny Tastes charts in the pack provided; these are for recording your children's progress. Each chart lasts for 14 days, so you will only need to use one chart for each twin to play the Tiny Tastes game for Gemini. There are lots of spare charts so you can carry on playing Tiny Tastes with different vegetables in the future if you like.

If possible, we would like you to play Tiny Tastes with each twin separately. We understand that this may be difficult but it will prevent them copying one another. The day after you have finished 14 days of Tiny Tastes, we would like you to complete the final test (Test 3). Please send back all three test record sheets and the two Tiny Tastes charts (one for each twin) that you filled in when playing the Tiny Tastes game, in the freepost envelope provided.

Step 1
Complete test 1.

→

Step 2
After 15 days complete test 2.

→

Step 3
The day after test 2, start playing Tiny Tastes every day for 14 days.

→

Step 4
15 days after Test 2 (and after playing 14 days of Tiny Tastes) complete test 3.

To see a short film demonstrating how to play Tiny Tastes please visit: www.tinytastes.org

If you have any questions about Tiny Tastes or you are confused about any of the instructions please call Alison Fildes 0207 6791263 or email the Gemini team:
Gemini@public-health.ucl.ac.uk

Good Luck!
The Gemini Team

Appendix 3.7. Example of a completed 'Tiny Tastes' intervention record sheet

Appendix 4. Publications and conference presentations

Appendix 4.1. List of the papers that I have worked on during my PhD, and the conferences that I have presented at and attended

Published papers:

Fildes A, van Jaarsveld CHM, Wardle J. & Cooke L. (2013). A randomized controlled trial of parent-administered exposure to increase children's vegetable acceptance. *Journal of the Academy of Nutrition and Dietetics.*

Fildes A. & Cooke L. (2012). "The munch bunch: healthy habits start at weaning." *Journal of Family Health Care*.

Cooke L. & **Fildes A**. (2011). The impact of flavour exposure in utero and during milk feeding on food acceptance at weaning and beyond. *Appetite*.

van Jaarsveld CHM, Llewellyn CH, **Fildes A**, Fisher A, & Wardle J. (2012). Are my twins identical? Parents may be misinformed by prenatal scan observations. *British Journal of Obstetrics and Gynaecology.*

Papers under review or in preparation:

Fildes A., van Jaarsveld C., Llewellyn C., Fisher, A., Cooke, L., Wardle, J. (2013). Parental control over feeding in early infancy: associations with infant weight, feeding method and infant appetite. (Under review)

Fildes A, van Jaarsveld CHM, Llewellyn C, Fisher A, Cooke L, Wardle J. (2013) Nature and nurture in children's food preferences. (Under review)

Fildes A, Llewellyn CH, van Jaarsveld CHM, Cooke L & Wardle, J. (2013). The heritability of responses to an exposure-based intervention to increase acceptance of vegetables. (In preparation)

Fildes, A, Llewellyn, C, van Jaarsveld, CHM, Fisher, A, Cooke, L, Wardle, J. Common genetic architecture underlying food fussiness in children, and preference for fruits and vegetables. (In preparation).

Fildes, A., Moschonis, G., Lopes, C., Moreira, P., Oliveira, A., Mavrogianni, C., Manios, Y., Wardle, J., Cooke, L., (2013). The TASTE study: A randomised control trial of parental advice for increasing vegetable acceptance in infancy. (In preparation)

Fisher A, McDonald L, van Jaarsveld CHM, Llewellyn C**, Fildes A,** Wardle J. (2013). Shorter sleep is associated with higher energy intake in infants. (In preparation)

Conference presentations:

Fildes A, Llewellyn C, van Jaarsveld CHM, Fisher A, Cooke L and Wardle J. Nature and nurture in children's food preferences. Poster at the **UK Society of Behavioural Medicine**, Stirling, Scotland, December 2011.

Fildes A, Llewellyn CH, Fisher A, van Jaarsveld CHM and Wardle J. Parental feeding styles in early infancy: are they shaped by maternal or child characteristics? Oral presentation (delivered by a colleague) at **The Obesity Society**, Florida, United States, October 2011.

Fisher A, Llewellyn CH, van Jaarsveld CHM**, Fildes A** and Wardle J. Sleep and weight in infancy. Poster presentation at **The Obesity Society**, Florida, United States, October 2011.

Fildes A, Jane Wardle & Cooke L. The impact of parental guidance on early exposure to a variety of vegetables on infants' liking and consumption: preliminary results of the TASTE study. Poster presentation at the **Association for the Study of Obesity,** Leeds, UK, June 2012

Fildes A, Wardle J & Cooke L. Early exposure to vegetable variety on infants' liking and consumption: the TASTE intervention study. Poster presentation at **VIVA Conference**, St Andrews, Scotland, March 2013.

Fildes A, Jane Wardle & Cooke L. Early Exposure to Vegetable Variety on Infant's Liking and Consumption: preliminary results of the TASTE study. Invited talk at the **Feeding Disorders Conference**, Great Ormond Street Hospital for children, London, June 2012

Fildes, A, Llewellyn, C, van Jaarsveld, CHM, Fisher, A, Cooke, L, Wardle, J. Common genetic architecture underlying food fussiness in children, and preference for fruits and vegetables. Oral presentation at **The European Childhood Obesity Group Congress**, Liverpool, England, November 2013.

Fildes, A, Llewellyn, C, van Jaarsveld, CHM, Fisher, A, Cooke, L, Wardle, J. Nature and nurture in paediatric food preference. Poster presentation at **The European Childhood Obesity Group Congress**, Liverpool, England, November 2013.

Fildes A, Llewellyn CH, Fisher A, van Jaarsveld CHM and Wardle J The Heritability of Responses to an Exposure-based Intervention to Increase Acceptance of Vegetables. Poster presentation (delivered by J Wardle) at **The Obesity Society**, Atlanta, Georgia, United States, November 2013.

Other conferences I have attended:

Cumberland Lodge, June 2011. Three day conference for PhD students of the Epidemiology and Public Health department at UCL, entitled 'Paving the way to health and wellbeing: exploring the role of behaviours and the social environment' including speakers Professor Andrew Steptoe.

Cumberland Lodge, July 2013. Three day conference for PhD students of the Epidemiology and Public Health department at UCL, entitled 'From science to society: Translating evidence into policy and programmes for the 21st Century' including speakers Sir Michael Marmot, Professor Ian Philp, Professor Nora Groce and Professor Mike Kelly. Along with two other students I was responsible for planning, organizing and running the conference.